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## FOURTH SERIES

## VOL. XIX—[WHOLE NUMBER, CLXIX.]

WITH TWO PLATES.

NEW HAVEN, CONNECTICUT.
1905

253628

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. I.—*The Submarine Great Canyon of the Hudson River*; by J. W. SPENCER, A.M., Ph.D.*

CONTENTS:

An Account of what has been done before this date.
The Hudsonian Canyon.
Surface Channels of the Continental shelf, and the Deep one of the Connecticut.
Constitution of the Continental shelf.
Origin of the Canyon.
The Magnitude and the Time of the Great Elevation.
Summary and Conclusions.

### *An Account of what has been done before this date.*

The early work of the Coast Survey brought to light a depression extending from near New York to the border of the Continental shelf. Prof. J. D. Dana was the first to recognize this feature as the submerged channel of the Hudson River, formed when the continent stood at a greater altitude above the sea than it does now. So much importance did he attach to it, as evidence of terrestrial oscillations, that a map of it appeared in all the editions of his Manual of Geology, since 1863, but only in the latest edition (1895) was it shown to reach to a greater depth than 720 feet. In the last revision the upper channel and the canyon sections are distinguished, the latter to a depth of over 2000 feet. But the discovery of the canyon was first announced by Prof. A. Lindenkohl in 1885† and further discussed in 1891.‡ He found that it reached to a depth of 2844 feet where the adjacent continental shelf was submerged to only 420 feet—a gorge of 2400 feet in

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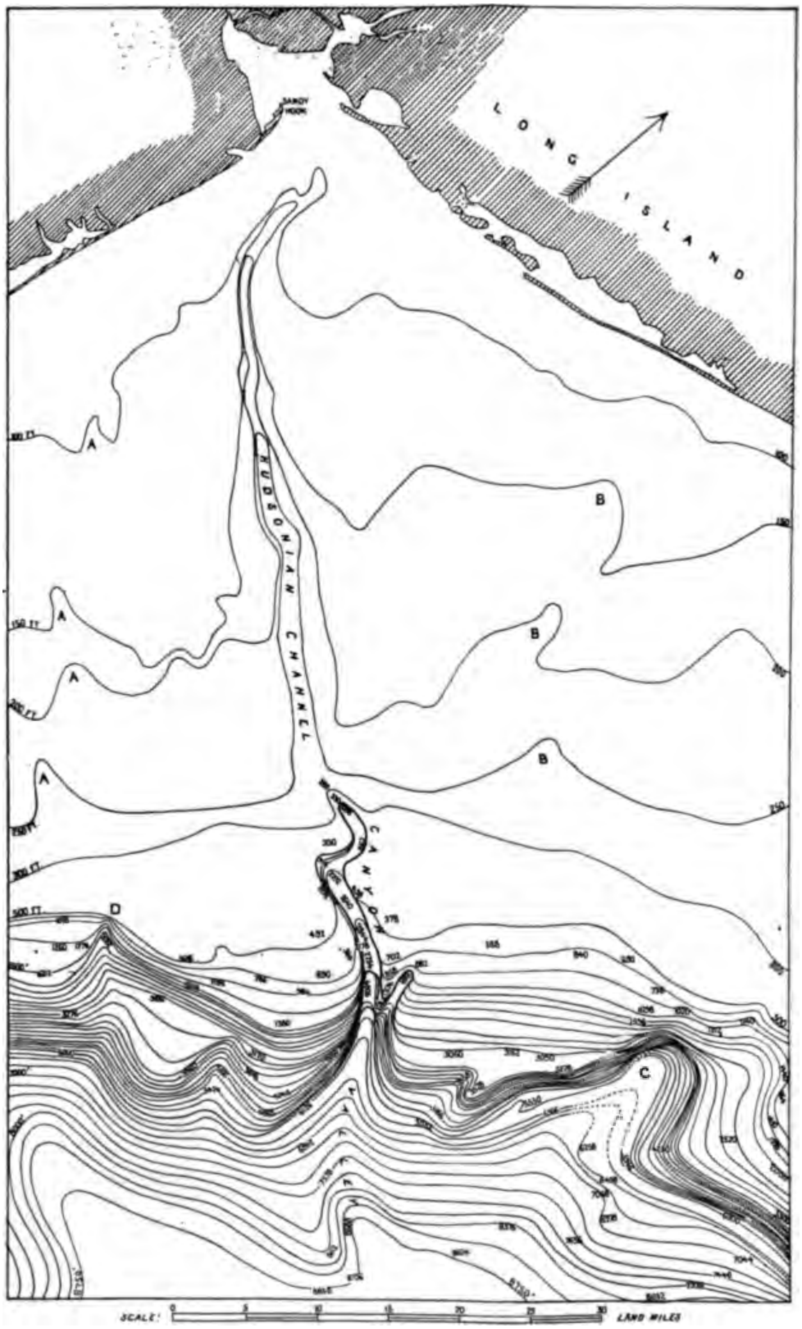
* This paper will simultaneously appear in the Geographical Journal of London.

† This Journal (3), vol. xxix, pp. 475–480, 1885.

‡ Ib., vol. xli, pp. 489–499, 1891.



Map of the Submarine Great Canyon of the Hudson River (by J. W. Spencer).

Soundings in feet. Isobathic lines 250 feet apart, from that of 500 feet to 8,750 feet. Very numerous soundings on continental shelf to 500 feet where the isobaths are 50 feet apart. A A A A and B B B show course of streams during a late Pleistocene elevation of 250 feet. C is position of the Connecticut canyon or *valley, west of* which are blank spaces in which the corrected soundings should be *896 and 2,340 feet.*

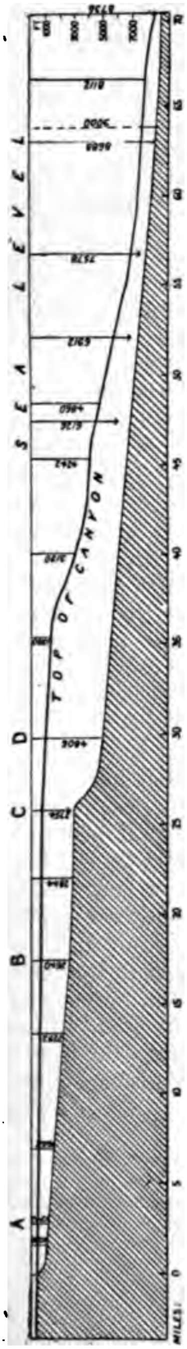


**FIGURE 1.**—Longitudinal section of Submarine Great Canyon of the Hudson River. At points where depths end in arrows the soundings were not taken in center but on side of the valley. A, E, B, C, D, location of cross sections. E is situated 4 miles above B. Soundings given in feet.

Since going to press, from additional information, abrupt steps of 400 and 500 feet respectively are found to occur in the gradient just above depths of 1662 and 2292-foot soundings.

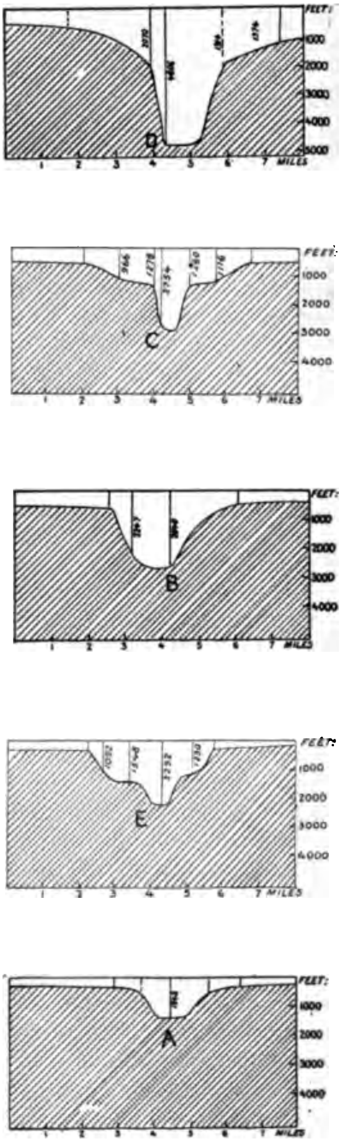


**FIGURE 2.**—Cross sections located at A, E, B, C, D, in longitudinal sections. Their position on map corresponds to similar depths, in feet, there shown. E (at a point 4 miles above B) and C show the double character of the canyon.

depth. From the soundings beyond the deep point, he at first thought a bar of 1600 feet in height crossed the mouth of the canyon.

In 1889, I pointed out that this canyon, along with those at the mouth of the Gulf of St. Lawrence and of the Maine, could be taken as yardsticks in measuring the late continental elevation to the extent of 3000–3600 feet. This was in the second paper published by the Geological Society of America, the first being by Prof. Dana.*

A few months later Dr. Warren Upham cited the Hudson canyon among the evidence he brought together to show that elevation was the cause of the glacial period.† In it he attributed the apparent bar to the action of coastwise wave-wash during the subsidence of the continent after the formation of the gorge. Though this bar was a large order for wave action, it was the only reasonable explanation of the deep hole if such it were, as suggested by the Coast Survey chart.

Again in 1890, Prof. Dana published a paper,‡ in which he says that the channel "affords strong evidence of the river origin and therefore the whole channel up to New York was once the course of the Hudson." In the last edition of his Manual he further says (page 948) that the former emergence of the continental border now sunken is proved by the Hudson submerged valley, citing also the cases of the canyons of the gulfs of St. Lawrence and Maine, mentioned above, as evidence of the elevation of the region in the glacial period to at least 3000 feet. It may be here stated that Prof. Dana, on seeing my account of the submarine valleys of the West Indian region, wrote to Prof. Lindenkohl, who replied that he was not aware of them, and hence the note in his Manual concerning them (page 949). Prof. Lindenkohl, however, later accepted my interpretation of the much deeper valleys§ which Dana doubted, confirmed by Prof. Lindenkohl's want of knowledge at the time, though Prof. Dana accepted my St. Lawrence canyon to 3600 feet below sea level.

In 1897 I read a paper before the British Association, stating that with the very insufficient soundings, the Hudsonian valley was recognizable to a depth of 12,000 feet,‖ illustrating how we may anticipate where canyons may be found. This paper, amplified into "The Submarine Valleys off the

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* "The High Continental Elevation preceding the Pleistocene Period," Bull. Geol. Soc. Am., vol. i, pp. 65-70, 1890.

† Bull. Geol. Soc. Am., vol. i, p. 563. Also Geol. Mag. Lond. (3), vol. vii, p. 494, 1890.

‡ "Long Island Sound in the Quaternary era, with Observations on the Submarine Hudson River Channel," this Journal (3), vol. xl, p. 425, 1890.

§ Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

‖ Ib., pp. 207-226.

American Coast," in 1902,* taking such phenomena as a whole, showed there was accumulative evidence suggesting that these submarine features were gauges for measuring the late great continental elevation.

The most recent discussion including that of the Hudsonian channel (1904) is in Dr. F. Nansen's epoch-making monograph on continental shelves and previous oscillations of shore lines,† reserved for later consideration.

### *The Hudsonian Canyon.*

The channel described by Lindenkohl begins about ten miles off Sandy Hook and extends for 93 miles before it plunges into the canyon. Land miles and not sea miles will be used throughout this paper. At its head, opposite Sandy Hook, the channel is buried by the sand of the coastwise drift-forming bars, though nearer New York it is much deeper. Lindenkohl had described the depth of the canyon to 2844 feet below sea level, with a bar in front, and no further information is shown on the U. S. Coast Survey charts. In revising my last mentioned paper, I found much additional data on the charts issued by the Hydrographic Office, greatly strengthening the evidence of the continuation of the Hudsonian valley, extending down the continental slope to great depths. But on the British charts I made a most astounding find of three soundings of 459, 801 and 229 fathoms. The position of the 459 and of the 801 soundings of the British chart so closely coincided with those of the Coast Survey chart‡ at 213 and 345 fathom points that they could not have been represented on the same charts. Thus the British chart showed no barrier to the canyon and very greatly increased the known depth of the narrow gorge, further defined by the 229 fathom point. The extraordinary depth would have been startling had it not been anticipated in all of my long series of analyses of submarine valleys. Both series of soundings were correct, the deeper ones having been made by Lt. Com. Z. L. Tanner§ in 1883 in the Fish Commission steamer Albatross. The older soundings had been retained on the Coast Survey charts.

The canyon of the Hudson River may now be extended and revised as follows: The mean edge of the continental border may be taken at a depth of 450–500 feet below sea level. The head of the canyon, in a direct line backward of the edge of the shelf, is 20 miles, but its course is somewhat longer. The upper channel has a depth of 42 feet in the very level sandy plain, which is then submerged to only 288 feet (though a hundred miles from New York harbor). At this point there is an abrupt descent from the bed of the upper part to 1098 feet in the canyon, within the distance of about a mile. The gorge soon deepens to 1242 feet, where cross section A is taken.

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* Ib.

† "The Bathymetrical Features of the North Polar Seas, with a Discussion of the Continental Shelves and Previous Oscillations of Shore Lines," by Fridtjof Nansen. Quarto, pp. 1–232, plates 28. Published in English by the Fridtjof Nansen Fund for the Advancement of Science, Christiania, 1904.

‡ Coast Survey Chart, No. 8. B. A. Chart No. 2480.

§ Hydrographic Notice to Mariners, No. 56, 1883.

The canyon extends nearly dne east for six miles, where its depth reaches to 1662 feet. It then bends sharply at right angles to the south, and at 12 miles from its head a narrow inner gorge descends from 1770 to 2292 feet (in a distance of 1·5 miles) where the broad outer canyon attains a depth of only 1500 feet below sea level. Here the shelf is submerged about 250 feet, accordingly the outer and inner canyons have respective depths to 1250 and 2050. A cross section is shown in figure E (added since paper went to press) which is located near the soundings of 2292 feet shown on the map and longitudinal section. Here the canyon turns again at nearly right angles towards the east, though farther on it bends slightly southeastward. A depth of 2640 feet is reached in 18 miles, where cross section B is taken. At 23 miles the depth is 2844 feet, and at 26·5 miles is the position of the 213-fathom sounding, which was supposed to have indicated a bar, and close against which is the discovered sounding of 459 fathoms, as shown in the precipitous wall in cross section C. Nearly midway between these soundings is one of 457 fathoms (the last two not being situated quite in the center of the channel). These, with others on record, but not shown on the published charts, form a chain of soundings from one to two miles apart reaching to near the floor of the inner gorge, thus establishing its continuity. At this locality also, unpublished soundings further show the double canyon, the outer of which, with a breadth of four miles, is revealed to a depth of 1200–1300 feet below sea level, while the inner has a width not exceeding one mile but reaches to over 2800 feet. The gradients and depths of the canyon and their relation to sea level are shown in the longitudinal section figure 1. At 31 miles the 801 fathoms is found, close against that of 345 fathoms not shown on map. This last is on the side of the gorge, of 3800 feet, where the continental slope is further submerged 1000 feet. Here, too, is a great downward pitch in the gradient of 2000 feet in four miles. At this point the maximum breadth of the gorge, nearly 3800 feet above the floor of the canyon, does not exceed two miles, with the bottom necessarily narrower. Seemingly part of the slope of the wall where the deep sounding was found approaches 60 degrees. At 34 miles there is a short tributary from the north, heading in a typical cove. Beyond this point, where the sounding is more than 4806 feet deep, the canyon feature must continue for several miles at least. I have carried it to the 42-mile point, where the continental shelf is submerged to 3000–3500 feet. At this depth we have several soundings which show that the 3000-foot isobath continues in a direct line as if across the canyon without any known suggestion that it sweeps round into the form of a broadened embayment. Its parallelism to the 500-foot line of the edge of the shelf shows the remarkable regularity of this zone of the great slope. There is also suggested the remains of a shelf or bench of depth corresponding to the Blake plateau south of Cape Hatteras.

Within a few miles the canyon appears to broaden out, and yet at 48 miles there is a steep cliff of 2000 feet or more on its southern side. Here the floor exceeds a submergence of 6126 feet, as the measurement is not in the center of the valley, nor have we obtained the sounding on the opposite northern edge, the last in the gorge being 4800 confined within walls of 3800 feet, though the walls are known on both sides lower down. Indeed this depth is still below that of the continental slope at 48 miles. Evidently the canyon section must reach to a depth of from 6000 to 7000 feet, which also corresponds to the deep valley of the Connecticut. (C on map.)

Beyond the canyon section is the southern side of the extended valley, demonstrated by a line of soundings, though not at its summit. The four soundings at about 8688 feet are specially important as proving the continuation of the Hudsonian valley. The first of these is at 63 miles. At 67 miles the lateral bank is at least 624 feet high (probably 1000 feet at least above the floor), and our record carries the valley to 71 miles from the head of the gorge. The end of this lower reach does not exceed 14 miles in width, but fuller soundings may limit it to 8 or 10 miles. Thus the valley is shown to exist to a depth of 9000 feet.

Beyond this point there are no soundings in the line of the valley, but lateral ones on both sides are suggestive, and at 100 miles east of this study, at a little less than 12,000 feet, is an embayment of 30 miles in breadth, with the depth of a few hundred feet. This cannot be a meaningless feature, though not part of the present analysis.

The breadth of the canyon hardly exceeds a mile at its head, but it soon widens to two miles or more. From the second turn (see map) a breadth of four miles is maintained for the outer canyon. The deeper inner gorge is reduced to a width of one mile or less, and is more sinuous than the outer. Beyond the tributary it is wider, five or six miles, though possibly more, as the next sounding is farther away, but a little greater or less detail does not alter the general features, and the only important points left relate to the question of the canyon opening out into the valley and its depths, which the analysis shows is 6000–7000 feet, and farther on the characteristics are those of a valley rather than a canyon to 9000 feet below sea level.

### *Surface Channels of the Continental shelf and the Deep one of the Connecticut.*

The surface of the continental shelf is a marvellously flat plain, with a mean slope not exceeding three feet per mile. This condition represents a flat substratum, even though there may be hollows in it levelled over by sand deposits. Nearer than Long Island there is no trace of a moraine either buried or submerged. The surface of the plain is covered over with sea-washed sand, except in the Hudsonian channel. This adjective termination I have long used to designate the drowned sections of the river valleys. The sandy plain is traversed by shallow channels shown on each side of the map at AAAA and BBB. These would be still better followed if more isobathic lines were introduced. It is to a depth of 250 feet that these channels are most noticeable. They represent the stream action of an epoch of elevation to this amount since the time of canyon making, and subsequent to the levelling over of the plain after that date. That is to say, these channels absolutely belong to a post-Columbia or Pleistocene epoch,—the canyons to a pre-Columbia or early glacial time. During Columbia oscillations wave action has obliterated all traces of delta form.

The channel of the Hudson river in crossing the submarine plain shows a bottom of blue clay with sandy material in places. But the course of the old upper channel must have been still defined to have allowed its reopening during the epoch of reëlevation of 250 feet just mentioned.

In the canyon section, the bottom is composed of blue clay with fine sand. Beyond it the continental slope is also surfaced with blue clay or green clay, as shown by many soundings.

The great Connecticut canyon or valley, asked for by Lindenkohl,* is represented (at C on the map) by a deep embayment, whose west wall is at least 3600 feet high, and it reaches to a depth of 5736 feet below the surface of the sea, but the information is not at hand to define its form, though a canyon perhaps passing into a valley at this point might be expected.

At D, on the other side of the map, one sees a cove or amphitheatre such as are commonly indenting the borders of high plateaus. I may have too strongly represented the feature on the map, but it is not one of special importance.

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* Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

### *Constitution of the Continental Shelf.*

All our classic teaching tells us that, during the earlier and middle Mesozoic era and far into the Cretaceous period, the continent here was so elevated and subjected to denudation that the sediments were carried far seaward. We cannot go into the question as to their covering the continental slope, but it would seem that the continental shelf now submerged was subjected to the same conditions as those now underlying the coastal plains of the adjacent lands. On these we learn that besides a few hundred feet of Potomac sands, which probably thin out, there are deposits of sand, greensand, clay and clay marl of the upper Cretaceous formations reaching a thickness of 800–1100 feet. Then follow some Eocene sands succeeded by clayey, marly and sandy beds belonging to the Miocene beds. These occur in an artesian well boring at Atlantic City, reaching to a depth of 1400 feet (without penetrating the series or the limited Eocene sands or obtaining water at the lower depths though somewhat higher fresh water occurs, indicating the leaching out of the salt sea water during an epoch of elevation). All below 265 feet is Miocene. This upper part is composed of sand gravel and clay, which may represent important features requiring a word of explanation. Of red gravel sand and stiff clay loam are composed both the Lafayette and Columbia formations, each of which is a thin sheet except where filling valleys. The Lafayette is provisionally regarded as belonging to the end of the Pliocene period, occurring below morainic material as I have seen in New Jersey. But it has been enormously denuded. The Columbia formation (now subject to subdivision) is the material of the Lafayette redeposited, and overlies the drift, with its surface only moderately sculptured. I should suspect that at Atlantic City is a buried channel filled mostly with these deposits of the Columbia period, capped with more recent alluvium. These upper beds are substantially horizontal, with the Miocene dipping a litttle more. For the details of the Miocene deposits in the Atlantic City well see the paper by Mr. L. Woolman*.

Thus not knowing whether these incoherent formations have a greater or less aggregate thickness, beneath the submerged coastal plains, there are only known little over 2200 feet to be accounted for from the adjacent shores. But they have formed the subsurface of the level plains now submerged, and channelled by the drowned Hudson river, and finally incised by the canyon on the continental border. Here then, in its upper portion, the gorge penetrates easily denuded material, though some of the beds are composed of remarkably tough clay. Where the sides of the canyon are so precipitous as was shown at the 459 and 801-fathom isobaths, we may suppose that the lower portions are cut out of the harder older rocks, succeeded by more yielding material farther down the submarine valley.

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* Acad. Nat. Sc., Phil. 1887, p. 339, and vol. for 1890, pp. 132–147.

### *Origin of the Canyon*

It appears that the previous students of the submarine channel have all had the idea that it was formerly a land valley. Such analysis of the phenomena as has been given must be used in discussing its origin under any other hypothesis. While a few other soundings are desirable for fuller local details, we need not one more for a reasonably full discussion of the principles involved—only enough are wanting to stimulate interest in a revision. Not to speak of similar phenomena farther south and in the West Indies discovered by myself,* and those since brought to light and systematized in a brilliant manner by Prof. Edward Hull of London, situated on the eastern side of the Atlantic basin,† I shall mention the canyon of the Congo discovered by Stassano, and worked out by Mr. J. Y. Buchanan and described by Mr. Edward Stallibrass, and the canyon off Cape Verde described by Mr. Henry Benest, on account of the completeness of detail of such features, not hitherto obtained, but with which the Hudsonian canyon can now be grouped with the advantage of our knowledge of the surrounding physiographical and geological environments, and with the further interest in that it is situated at the main door of the continent.

If formed by river action, the Hudsonian canyon affords proof of startling physical conditions of the region, at a very late date, and hence the whole interest in its origin, for if now a land feature, it would be one of not such unusual occurrence as to awaken our amazement. Can the views of the earlier writers be challenged? The only other possible causes of its origin seem to be:—(1) submarine glacial erosion, (2) open faults, (3) submarine rivers, and (4) a remnant of a primitive depression. This last would only be suggested by an obstinate objector to its fluviatile origin, or one unfamiliar with the analyses of such subjects; for after passing the Paleozoic evolution of the continent, what is now its great slope should be covered with detritus carried into the sea during the long period of denudation of the Mesosoic era, thus obscuring older depressions. Some of the African canyons have been attributed to submarine rivers. By this the hypothesis of a great elevation of the continent was avoided. There seems nothing in its favor beyond the occurrence of river valleys at great depth, and some floating debris on the sea. As Prof. N. S. Shaler says, subterranean channels must be formed above the base level of erosion; and the establishment of such must precede that of submarine rivers, which soon lose their effectiveness.

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* "Reconstruction of the Antillean Continent" and other papers in Bull. Geol. Soc. Am. and in Quar. Jour. Geol. Soc. London.

† Published by the Victoria Institute, London.

Can the question of canyons be cavalierly disposed of by calling them faults? The level continental shelf is covered with Tertiary sands and clays, such as would not favor an open fault theory. The submarine topography on both sides is identical, suggesting not the slightest disturbance to leave an open fault, nor is such shown on the land adjacent. Joints and faults may locate valleys, but the submarine shelf is only a new plain prolonging the Hudson valley, which in slowly rising would force the water to follow the lowest course. The fault theory is not supported by the Great Valley of the Appalachians, extending for a thousand miles, with a breadth of from 20 to 40 miles. And it is in a region abounding in fault; yet the valleys, as have long since been shown by Professors Lesley and Dana, and others, are those of denudation and which I have confirmed in Georgia. Even the gorge of the Delaware Water Gap, where more than a tyro might be pardoned for suspecting a fault left open, is not such according to Professor Lesley and Mr. Chance the geological surveyor of it. The submarine canyon of the Hudson, which is double, the inner the more sinuous, does not lie in a direct line, but turns twice at right angles within a distance of a dozen miles, and below, it widens into a fan-shaped valley. Nansen has described many submarine valleys in the continental shelf of Norway and about Iceland, and does not find it necessary to call in the existence of faults, and even where my evidence has not been full in treating deep submarine valleys, he thinks there is no other feasible explanation, than that the valleys are sunken land features (page 192). Nor will those who appeal to Sir A. Geikie find much comfort in faults. He says:—"To many geologists the mere existence of a valley is evidence of the presence of a fault," and that "in every case actual proof of a fault should be sought for in the tectonic structure of the ground." "In the vast majority of cases in Britain valleys have no connections with faults." From its forms and its associations I think we can dispense with the idea of a fault-made rift, unaffected by atmospheric action; and furthermore, this is not in the region of apparent great tectonic disturbances, but one of remarkable simplicity since in Cretaceous times.

Finally I know of no other reason for appealing to faults as the cause of such a submarine feature, except as a last resort from accepting the evidence as is set forth in this paper, unless such a reason can be shown to exist other than by negative or insufficient evidence.

As for submarine glacial erosion, I have shown that there are no features of the shelf suggestive of the occurrence of glacial action, even though such reached to Long Island and New Jersey. Furthermore it could not have possibly extended to the great depths of the canyon and the continuing valley. Of this question Dr. Nansen says in his great monograph:—"The drowned valley of the Hudson River cannot possibly have been re-opened by submarine glacial erosion, it is too long and narrow and deep." (Op. cit. p. 192.) Its analogues of the tropics are situated beyond glacial action.

Of the drowned valley of the Gulf of St. Lawrence, Prof. N. S. Shaler also writes, but I do not remember whether he considers the then discovered Hudson River canyon.

Returning now to long accepted fluviatile origin of the submarine channel, let me call attention to the very close resemblance of the canyon, as shown on the map, to the gorge of the Niagara, also excavated out of level plains, far from mountains, in front of which are great slopes to lower levels. But this portion of the Hudsonian canyon is thirty miles long and reaches to thousands of feet in depth, while that of the Niagara is only seven miles in length and now 440 feet deep. So too the canyon of the Hudson is just like the *barrancas* on the high plateaus of Mexico and Central America, starting in level plains, and then suddenly transforming themselves into rapidly descending canyons, which later widen out into such valleys (as we may see in the east, which have reached more mature forms), whose descent from the plateaus of thousands of feet in height is not by regular gradients, but commonly by a succession of great steps.

### *The Magnitude and the Time of the Great Elevation.*

While it must have taken the Hudsonian canyon many milleniums to have been formed, yet it presents a youthful feature, in strong contrast with the valleys on the eastern side of the American continent, while its submerged marginal shelf is not deeply indented with its surface scored into a succession of ridges and hollows. Even though many of the underlying rocks may be of a resisting nature, yet the period of canyon-making must have been one of limited duration. This is further suggested when considering the size of the Hudson river, which probably carried down glacial waters and detritus for a portion of the period. Outside the limit of the Hudsonian river, the surface of the now submarine plain was not deeply scored as with atmospheric agents acting for long ages, as would have appeared beneath the superficial mantle had such obtained. One condition might modify this last argument, namely a subsequent long epoch of wave cutting, with the removal of the prominences, such as Nansen describes in his "coast platform" which does not exist here, but in such a case the Hudsonian gorge should have been filled with debris.

In the region of the Great Lakes from the tilting of beaches, I have worked out great epirogenic movements, and it quite prepares me to expect to find a reduction of the amount of elevation of the continent, represented by the present submergence of the valleys along our continental margin due to bending downward of the continental slope, but this would not reduce by any amount that determined in the canyons and the necessary slope of the land surfaces. So also when we find subaerial features submerged, they at least would need to have been depressed to the depth they are now found at, no matter what the cause of depression.

The canyon section has sunken 6,000–7,000 feet and the valley beyond to 9,000 feet. Did I attempt to guess at the reduction of this amount in the late height of the continent, I should be inclined to pause owing to other features outside the line of this study. But if others wish to reduce the continental elevation by 2,000 feet, by extra bending down of the continental slope, I shall not protest farther than by stating that additional evidence beyond our limit may replace it. Provisionally then we may keep the amount of elevation at 9,000 feet as shown here, leaving others to correct the figures if found to be excessive. On the other hand, I have no idea that the present heights of the mountains were relatively nearly so great as now.

Fragments of the Lafayette formation should extend from New Jersey, and underlie the surface of the continental shelf. The great denudation of the region was after the Lafayette period, as was proved by Prof. W. J. McGee. I have found these beds underlying glacial deposits in New Jersey. They are provisionally regarded as Pliocene, unless they are preglacial Pleistocene, as thought by Upham. On the surface of the overlying till, rests the Pleistocene Columbia red loams, sands and gravels, in samples not distinguishable from those of the Lafayette formation except in the smaller size of the gravel. And it is such materials which are obtained in the Atlantic city well (Woolman). The denudation of the Lafayette has been so extensive that its remains would be more likely outside of a channel, buried as this appears by the Columbia formation, which has levelled over and furnished materials for the surface of the continental shelf before the re-excavation of the small channels at AAAA and BBB on the map (page 2). These channels as mentioned before, represent a re-elevation of the drowned plain to as much as 250 feet in the later Pleistocene period, since which time the region has been again once or twice depressed, then re-elevated slightly and channelled, and is now sinking at the rate of two feet a century (Prof. Mitchel). All of the changes are remarkable repetitions of those which I have shown to have occurred farther south and in the West Indies. Thus it may be seen that the canyon-making period was in the earlier Pleistocene, and accords with Prof. Dana's views as expressed in the last edition of his Manual, and those of Dr. Upham, only the evidence is in more detail, showing a much greater elevation than was then known.

I have not touched upon an earlier Tertiary valley, as such could apply only to great depths beyond the canyon section.

### *Summary and Conclusion.*

More than 40 years ago, Prof. J. D. Dana first recognized the submarine extension of the Hudson river in the soundings on the continental shelf. In 1885, Prof. A. Lindenkohl discovered the channel suddenly transformed into a canyon near the continental border, reaching to a depth of 2400 feet below the surface of submerged plain, which is here about 400 feet beneath sea-level. But near the then known mouth there appeared a great bar. In 1897, I pointed out that the channel was traceable to great depths, which is now proved. A sounding was made near the supposed bar, which has proved to be only a measurement taken on the side of a deep canyon with a precipitous wall. Then four miles beyond this point, against another lateral bank, a further sounding reaches to 4800 feet, revealing a canyon 3800 feet in depth, where the continental shelf is not submerged more than 1000 feet. High up on the sides, the gorge here is less than two miles wide, but the incision of the outer canyon into the shelf has a breadth of four miles. At its head, the canyon begins in an amphitheatre, having a descent from 330 feet to 1100 feet in the distance of about a mile. Two more steps of 400 and 500 feet respectively follow. Again between 27 and 31 miles below its head, there is another great step of 2000 feet to the depth of 4800 feet mentioned. And the gradient below is probably by other great steps. This is just beyond the border of the submarine plain and shows the canyon with a depth of 3800 feet. The canyon is double, a second or more sinuous gorge traverses the outer. A little farther on is a tributary heading in a cove. At 42 miles the canyon begins to widen into a valley, which at 48 miles has a precipitous wall of 2000 feet in height. The valley opens into an embayment or wider valley which also receives that from the Connecticut, now discovered to a depth of about 6000 feet for the first time, but without details to describe its form. In cutting through the continental bench, at 3000–3500 feet beneath sea-level, the floor of the canyon is between 6000 and 7000 feet below the surface of the ocean. The valley is continuous to a point 71 miles from the head of the gorge and where it is recognizable at a depth of about 9000 feet.

The canyon and valley discovered to the great depth shown, incising first the level continental shelf, (in which it turns twice at right angles), and then coursing down the great continental slope, is now taken as a gauge for measuring a late high continental elevation of the region to the extent of 9000 feet. This is following out the lines of Dana, Lindenkohl and other students of the submarine channel, in that they considered it a drowned land valley. I have analyzed every other known possible cause of its origin. So great are the probabilities and so long have these been accepted unquestioned, that very strong proof would be required to modify this view.

The period of the great elevation has been found to coincide with that of the early Pleistocene. Since then there has been a subsidence to somewhat below the present level, followed by a re-elevation of 250 feet as seen in the shallow channels of the shelf. With other minor changes, the region is now sinking at the rate of two feet a century.

This canyon feature at our door corroborates the great changes of level worked out most extensively by Hull of Britain, Nansen of Norway, and myself here and in the West Indies, following methods which the father of geography, Prof. J. P. Lesley, predicted in 1888 "must throw light on the whole subject of elevation and subsidence, as applicable to the entire area of the United States."

## ART. II. — *Radio-activity of Underground Air*; by H. M. DADOURIAN.

ATMOSPHERIC and underground air have been shown to be radio-active by Elster and Geitel,[*] and others. Experiments, by several investigators, on the rate of decay and other properties of the atmospheric radio-activity have proved it to be due to the presence of a radio-active gas similar to radium emanation. The activity of this radio-active gas decays just about as fast as radium emanation, that is, it falls to half value in about three days and a half. But the rates of decay of the excited activities obtained by exposing a negatively charged wire to the air and to radium emanation do not agree so well. Rutherford and Allan[†] obtained 45 minutes for the half-value period of air excited activity, whereas radium excited activity falls to half value, after the first two hours, in 28 minutes.

This is to be expected if we suppose that there is thorium emanation in the air as well as radium emanation. Thorium emanation decays very rapidly, having a half-value period equal to about one minute; so the experiments on the rate of decay of the radio-active gas obtained from the air determine the rate of decay of the radium emanation in the air only, the thorium emanation having decayed during the few minutes which it takes to begin to observe the ionization currents, after the removal of the difference of potential from the negatively charged wire. This accounts for the close agreement between the rates of decay of the ionizations of radium emanation and the radio-active gas obtained from the air. On the other hand, the excited activity obtained by exposing a negatively charged wire to the air, decays very much more slowly than radium excited activity; the half-value period of the former is about 11 hours while that of the latter is 28 minutes. Thus measurements of the rate of decay of the air excited activity give the rate of decay of a combination of the excited activities of radium and thorium. In fact, Bumstead[‡] has recently shown that the excited activity obtained by exposing a negatively charged wire in the open air is fairly accounted for by the assumption of the presence of radium and thorium emanations in the air.

The following experiments were undertaken in order to see if this was the case with the excited activity obtained from underground air, also. The method employed in taking the ground-air excited activity is illustrated in figure 1.

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[*] Elster and Geitel, Phys. Zeit., iii, p. 574, 1902.

[†] Rutherford and Allan, Phys. Mag., Dec., 1902.

[‡] Bumstead, this Journal, xviii, 1, 1904.

A circular hole, AA, 50$^{cm}$ in diameter and 200$^{cm}$ deep, was dug in the ground. At the top of the cavity was plastered a rectangular board, CC, with a circular opening 40$^{cm}$ in diameter. A sheet metal cover, D, screwed on to the board, over a rubber gasket, served as a partition between the outside air and the air inside the cavity. BB is a wooden frame, which consists of a 175$^{cm}$ long rod, provided with a circular board, of 30$^{cm}$ diameter, at each end. A piece of copper wire, $\frac{1}{4}^{mm}$ thick and about 50 meters long, was wound about the frame, so as to form a cylinder. The wire was put into this form in order to have it as near the walls of the cavity as possible, also to secure a larger field. This cylinder of wire was then hung from a hook, E, which was insulated from the sheet metal cover and was connected to the negative terminal of a Wimshurst machine, the other terminal being to earth.

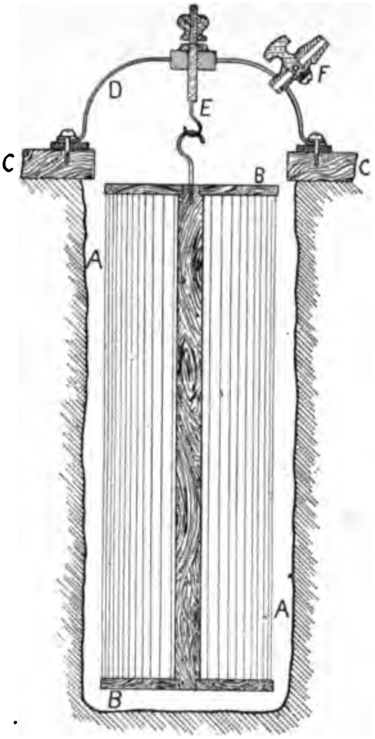

Fig. 1.

The wire was charged for three hours, keeping a parallel spark-gap of about 2$^{mm}$. In the meanwhile the air in the cavity was sucked out by means of a filter pump, connected to the stopcock, F, in order to bring fresh underground air into the field of the negatively charged wire. At the end of three hours the wire was removed from the wooden frame and was put into a testing vessel. This was a cylindrical condenser which consisted of a galvanized sheet-iron cylinder and a central brass rod, insulated from the cylinder and connected to one pair of the quadrants of an electrometer.* The needle of the electrometer and the testing cylinder were connected to the negative electrode of a set of dry cells giving a potential difference of 105 volts, the other electrode of the battery being to earth. The central rod of the testing condenser and the pair of quadrants it was connected with were earthed ordinarily, but could be insulated at will by pressing a key. The electrometer was very steady throughout the following experiments and had a sensitiveness of $250^{cm}$ per volt with 100 volts on the needle and the scale at one meter.

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* For a description of the electrometer, the testing cylinder and connections, see February (1904) number of this Journal.

The observations were taken in the following manner: The zero position of the needle was observed, then the central rod of the testing vessel and the quadrants it was connected with were insulated. Observations of the ionization current were taken at the end of half a minute, one minute and two minutes after the quadrants and the central rod were insulated; then these were earthed again. This was done at six-minute intervals for five hours, after which the activity of the wire decayed very slowly, and it was not necessary to take observations so frequently. The decay of the activity for the first four hours is given by curve I of figure 2, where the time is plotted as abscissae and the natural logarithms of the ionization currents as ordinates. The experiment was continued for three days,

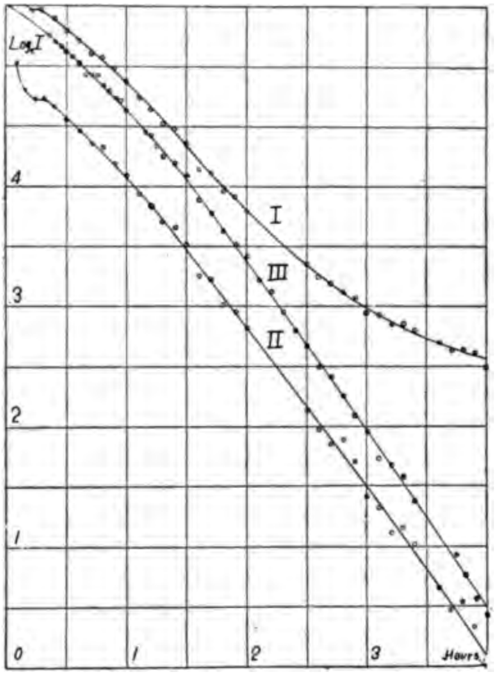

Fig. 2.

observations being taken at longer intervals. About five hours after the potential difference was removed from the negatively charged wire, the ionization due to radium excited activity was vanishingly small, all the activity, about five per cent of the total initial activity, being of a very much more slowly decaying type. The rate of decay of this slowly decaying activity was calculated from the data of two experiments; in one case the half-value period was 10 hours and 12 minutes, and in the other case it was 10 hours and 47 minutes, giving an average value of 10½ hours. This is very near the half-value period of thorium excited activity, which is about 11 hours. None of the excited activities of the known radio-active substances or a combination of them can account for the slowly decaying excited activity of ground air, except thorium excited activity.

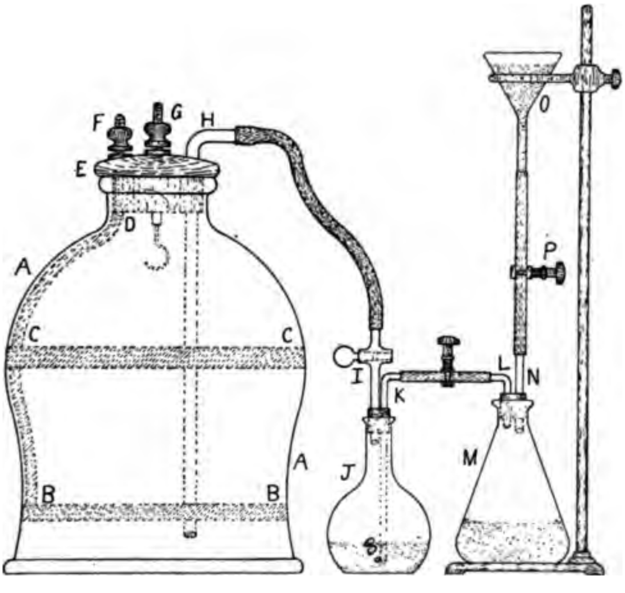

Fig. 3.

It is very improbable that there is an unknown radio-active substance whose excited activity falls to half-value in about the same time as that of thorium. Hence there is no reason to doubt that the slowly decaying activity obtained by exposing a negatively charged wire to underground air is thorium excited activity.

In order to see if the presence in the underground air of radium and thorium emanations was enough to account for the ground air excited activity, the following experiments were made:

A piece of copper wire, $\frac{1}{4}^{mm}$ in diameter and 2 meters long, was exposed to radium emanation in an apparatus shown in figure 3. The apparatus consists of a glass bell-jar, AA, $22^{cm}$ in diameter and $30^{cm}$ high. It is fitted with an insulating cap, E, provided with two binding-posts, F and G. The binding-post F is in contact with a strip of tinfoil, DCB, and through that with two other strips of tinfoil, CC and BB, all three being pasted inside the bell-jar. J is a flask containing a solution of radium bromide of 1000 activity, prepared by De Haan. A glass tube, I, provided with a glass stopcock, is connected by a piece of rubber tubing to another tube, H, which passes through the insulating cap, E, into the bell-jar and puts the latter in communication with the flask which contains the radium solution. Another flask, M, is connected with the flask J through two glass tubes, K and L, joined by a piece of rubber tubing carrying a screw pinchcock. Another piece of rubber tubing carrying a screw pinchcock connects a funnel, O, to the flask M.

The wire to be exposed to radium emanation was loosely coiled and was hung from a hook soldered to the lower end of the binding-post G. The latter was connected to the negative electrode of a storage battery of 100 volts, while the binding-post F was connected to the positive electrode of the battery. Thus an electric field was set up within the bell-jar. Then some water was poured into the funnel and the pinchcock, P, was regulated such that the water dropped into the flask M, drop by drop. Each drop displaces an equal volume of air, which bubbles out through the radium solution. This bubble in its turn forces part of the mixture of air and radium emanation in the flask J to go into the bell-jar. Thus the bell-jar is supplied uniformly with radium emanation. This rather elaborate method of exposing the wire to radium emanation was used to guard against particles of radium which might otherwise come into contact with the wire or the bell-jar. After the wire was charged for exactly three hours it was taken out of the bell-jar, was introduced into the testing cylinder and observations of the ionization currents were taken as described above. The results of the experiment are shown by curve III, figure 2.

The rate of decay of thorium excited activity also was taken by exposing a piece of copper wire, of the same dimensions as the one used for radium excited activity, to thorium emanation. The source of the emanation was about 10 grams of powdered thorium oxide, which was spread uniformly over a watch-glass and placed under the bell-jar. The wire was charged negatively for three hours and the rate of decay of the activity was observed as before. The results of two such experiments are shown by curves I and II, figure 4, where the ordinates represent the ionization currents and the abscissae the time. These curves have half-value periods of about 11 hours and agree very closely with those given by Rutherford.

The component due to thorium of the total ionization of the ground-air excited activity was calculated by a method to be described below, and was subtracted from the latter in order to compare the result and activity with radium excited activity. It is obvious that the resultant activity will be nothing more nor less than radium excited activity provided that the ground-air excited activity is composed solely of radium and thorium excited activities. It was shown above that the activity of the negatively charged wire exposed to ground-air was entirely thorium excited activity at the end of five hours after the removal of the potential difference from the wire. Hence the thorium element of the ground-air excited activity at any time can be found by multiplying the ionization of the thorium excited activity, for the corresponding time, by the ratio of the ionizations of the ground-air and thorium excited activities at any time after five hours. The ratio of the ionizations, at the end of nine hours of the ground-air and thorium excited activities, represented by the curves I of figures 2 and 4 respectively, was found to be 0·0216. Each of the observed values of the ordinates of curve I, figure 2, was multiplied by this ratio and

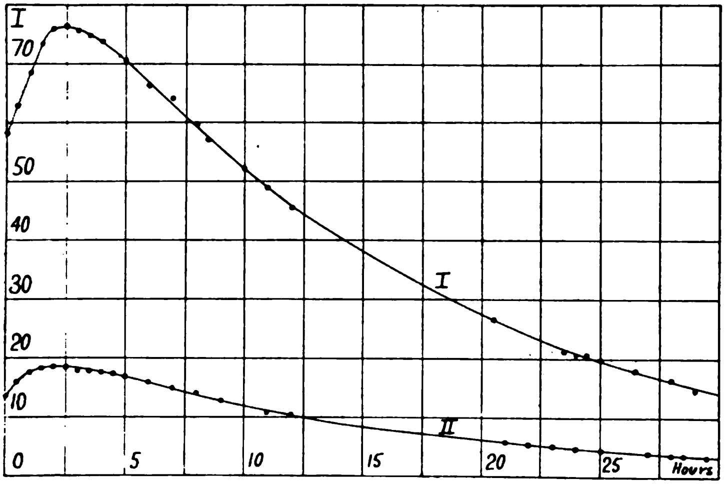

Fig. 4.

the product was subtracted from the former. The results when plotted gave curve II of the same figure, which represents the rate of decay of the ground-air excited activity minus the part due to thorium. A glance at figure 2 is enough to show the difference both in nature and rate of decay of curves I and III on one hand, and the agreement between the curves II and III on the other. Yet it will be observed that the latter are not exactly parallel; curve II slopes at a little slower rate than curve III. Hence apparently the ground-air excited activity decays at a slightly slower rate than a combination of radium and thorium excited activities, in the same proportion as they occur in the ground-air excited activity. Bumstead has observed a similar disagreement between the rates of decay of the excited activity obtained from atmospheric air and a combination of radium and thorium excited activities.* No attempt will be made in this paper towards explaining the disagreement, as the writer is at present engaged in a series of experiments to that end, the results of which will appear in a later number of this Journal.

In conclusion, I wish to express my thanks to Professor H. A. Bumstead for his kind interest in these experiments and for his valuable suggestions.

Sheffield Scientific School of
Yale University, Nov., 1904.

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* Loc. cit. p. 7.

## Art. III. — *The Types of Limb-Structure in the Triassic Ichthyosauria*; by John C. Merriam.

### *Introduction.*

Of the numerous valuable contributions to paleontological literature made by the late Professor George Baur, one of the most interesting was that in which he furnished evidence that the limbs of the Jurassic Ichthyosaurs were highly specialized structures developed in adaptation to aquatic life.* In advancing this view he opposed the theory of Gegenbaur and others, who held that they were generalized and intermediate between the pentadactyle limbs of the higher vertebrates and the many-rayed extremities of the selachians. As was shown by Baur, the limbs of the Triassic Ichthyosaurs come nearer to the type of extremity found in the primitive reptilia than do those of the later representatives of the order. The character of the modification of the limbs, and in fact the whole structure of the body in the later Ichthyosaurs, indicated to him that, as a group, they bore the same relation to the Rhynchocephalia that the cetaceans bear to the primitive mammals.

At the time Baur wrote on this subject, the only available Triassic specimens showing the limbs were those from the bituminous shales of Besano in Lombardy. These he separated from *Ichthyosaurus* as a new genus, *Mixosaurus*.

Within the last few years considerable collections obtained from the Triassic of California have brought to light several new groups of Ichthyosaurians differing not a little from the previously known genera of Europe. So many new forms have appeared in this fauna that some of the questions relating to the origin and descent of the Ichthyosauria are reopened. The addition of new material has made the problems more complicated, but it is hoped that before we again reach the limits of profitable discussion it will be possible to add something to our knowledge of the origin and the history of the group.

### *Characteristics of known types.*

At the present time we are acquainted with not less than four types of limbs in the Triassic Ichthyosaurs. One of these is represented in *Mixosaurus*, a second in the genera *Toretocnemus* and *Merriamia*,† a third in *Shastasaurus osmonti* and

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* Ueber den Ursprung der Extremitäten der Ichthyoptergia, Ber. d. xx, Versamml. d. oberrhein. geol. Ver., xx, p. 3.

† See G. A. Boulenger, Proc. Zool. Soc. Lon., 1904, vol. i, p. 425. *Leptocheirus* Merriam being preoccupied is replaced by *Merriamia* Boulenger.

*alexandrae.* The fourth appears in a recently discovered specimen which seems to be specifically identical with *Shastasaurus perrini.* This form evidently represents a genus distinct from the type seen in *S. osmonti* and *alexandrae*, and the name *Delphinosaurus** may be used to distinguish it from the more specialized species.

In *Mixosaurus* (fig. 1) the extremities are of a primitive type. Both manus and pes are pentadactyle,† the elements of the limbs are generally quite slender and in many cases have a median constriction. This form is farther characterized by the articulation of the intermedium distally with two or more elements and by the frequent presence of a fourth element (pisiform) on the posterior end of the proximal row in the mesopodial region.

*Toretocnemus* and *Merriamia* do not differ greatly in limb structure though the vertebrae are of distinct types. In *Merriamia* (fig. 2) the limb has but three digits with the merest vestige of a fourth. There are but three elements in the first row of the mesopodial region and both carpus and tarsus are of a strictly linear type, the intermedium articulating with but a single element distally. In this genus the posterior limbs are much smaller than the anterior. In *Toretocnemus* the posterior limbs equal or exceed the anterior in size and the vestigial fourth digit of the posterior limb appears to have been larger than in *Merriamia.*

The most specialized limb found in the Triassic genera, and one of the most specialized types known in the Ichthyosauria, is seen in *Shastasaurus osmonti* (fig. 4). The anterior limb in this genus is characterized by extreme shortening of all the elements. The humerus is actually as broad as long and is one of the shortest propodial elements known in the reptilia. The epipodial bones are also greatly abbreviated, though separated by a narrow cleft. Of the carpus only the radiale is known. It is as large or larger than the ulna and its margin is entire, while that of the radius shows an anterior notch.

In the recently discovered anterior limb referred to *Delphinosaurus (Shastasaurus) perrini* (fig. 3) the humerus, radius and ulna are longer than in *S. osmonti*, and the radius and ulna are both deeply constricted. The radiale is narrower and is notched. The carpus is of the linear type and the posterior of the three linear series consists of somewhat smaller bones than are seen in the other two. The elements of the meso-

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* *Delphinosaurus* is characterized by much elongated vertebral centra ; an unnotched scapula, and the peculiar structure of the limbs described above.

† See redescription of *Mixosaurus*, E. Repossi, Atti. della soc. ital. d. scien. Natur., vol. xli, fasc. 3, p. 361-372, Tav. viii, ix.

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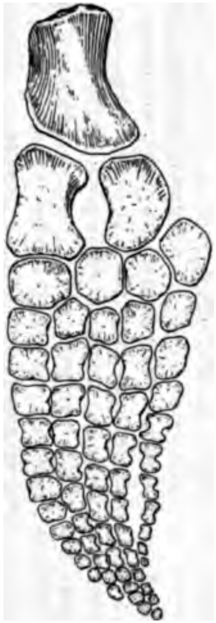

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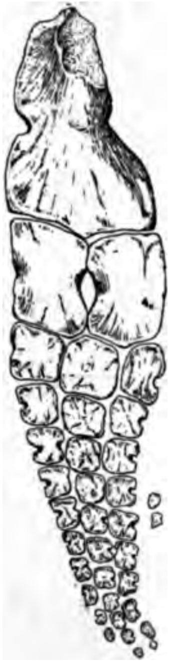

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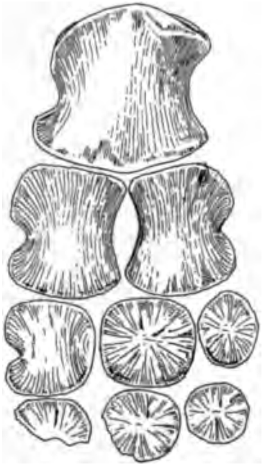

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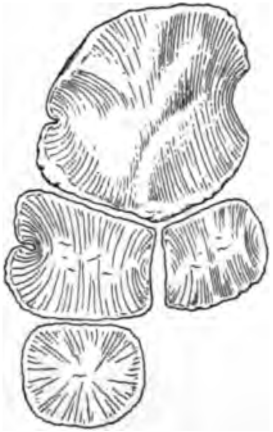

FIG. 1.—*Mixosaurus cornalianus.* Left anterior limb. × ⅓. Slightly modified from Repossi.

FIG. 2.—*Merriamia zitteli.* Left anterior limb. × [illegible].

FIG. 3.—*Delphinosaurus perrini.* Left anterior limb. × ¼.

FIG. 4.—*Shastasaurus osmonti.* Left anterior limb. × [illegible].

podial and phalangeal regions, as far as known, are rounded and have deeply excavated borders, showing that they lay in heavy pads of cartilage. Judging from the character of the carpus in *Delphinosaurus* and in *Merriamia*, the large radiale in *S. osmonti* indicates that the anterior digit of the manus was relatively larger and the third smaller in *Shastasaurus* than in the other forms. The limb would in that case be reduced almost to a two-fingered type.

### *Degree of differentiation.*

The degree of differentiation shown in the three or four types of limb structure known in the Triassic Ichthyosaurs

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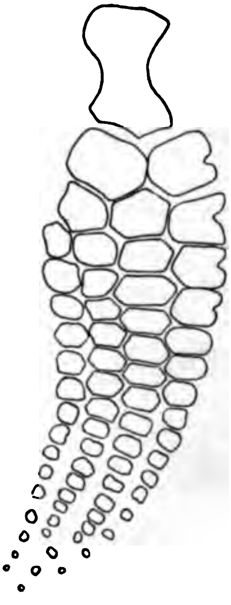

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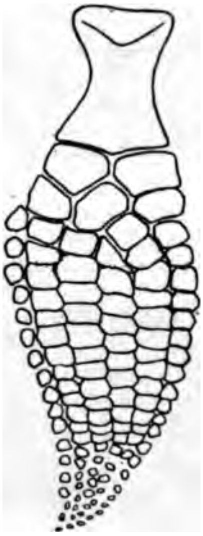

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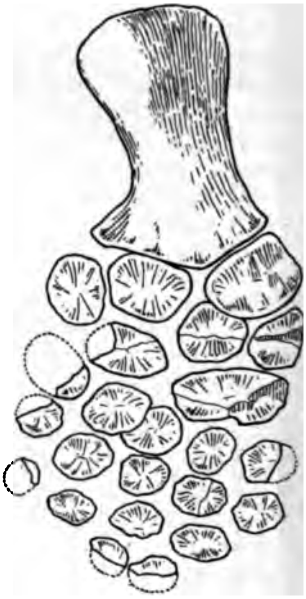

Fig. 5.—*Ichthyosaurus quadricissus.* Anterior limb. × ⅛. After Fraas.
Fig. 6.—*Ichthyosaurus conybeari.* Anterior limb. After Lydekker.
Fig. 7.—*Baptanodon marshi.* Anterior limb. After Knight.

appears quite remarkable when we compare it with what we find in the Jurassic genera. Three types of limb structure are known from the Jurassic. The most specialized of these is found in *Baptanodon* (fig. 7) and *Opthalmosaurus* with three very short elements in the epipodial region, five or more digits, and discoidal phalanges. In *Ichthyosaurus*, possessing two short epipodial elements, there are two groups. Of these the Longipinnati (fig. 5) have an essentially linear mesopodial region, a notched radius and usually three to five digits. The Latipinnati (fig. 6) have an alternate arrangement of the mesopodial region caused by the articulation of two or more distal elements on the intermedium ; there are generally between five and ten digits ; and notches are rarely present on the phalanges, while never on the radius. Compared with these three types the Triassic forms show an unexpected degree of differentiation.

### *Primitive characters.*

In spite of the differentiation shown in the Triassic types, they have all retained certain primitive characters not common in the later forms. All show a separation of the radius and ulna, and in all excepting *Shastasaurus osmonti* these elements are elongated and the radius is constricted or shafted. The presence of these and other primitive characters in so many otherwise different forms furnishes us with much stronger evidence of the origin of the Ichthyosauria from generalized shore forms than could have been given by the single type known to Baur.

### *Lines of descent.*

A comparison of the Jurassic and Triassic genera of Ichthyosaurs with a view to determining the lines of descent shows immediately that no known Jurassic form can be considered as having descended from the specialized *Shastasaurus.* So far as we now know, this group disappeared in the Triassic. *Baptanodon* and *Opthalmosaurus* are also practically excluded from any comparison with the Triassic genera, as they are comparatively late forms and could be derived from the latipinnate Ichthyosaurs as easily as from any of the much older Triassic types.*

The views which we hold concerning the descent of the remaining Jurassic groups involve our interpretation of the homologies of the elements in the Ichthyosaurian paddle. On this subject a considerable variety of opinion has been expressed, particularly with reference to the relationships of the mesopodial elements.

Some years ago Lydekker† suggested that the most generalized type of limb in the Jurassic Ichthyosaurs is found in the

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* Dr. O. P. Hay (Bull. 179 U. S. G. S., p. 463) has, I believe inadvertently, placed the West-American Triassic Ichthyosauria under the Baptonodontidae. Based on this suggestion, Boulenger (loc. cit.) has indicated the descent of *Opthalmosaurus* from *Shastasaurus.* The writer is obliged to regard these groups as probably the most widely separated of all the known Ichthyosauria.

† Geol. Mag., 1888, Decade 3, v, p. 310.

Longipinnati, such as *Ichthyosaurus tenuirostris*. The anterior digit was considered as representing digit II of the primitive limb, digit I having disappeared. Latipinnate forms, such as *I. intermedius*, were supposed to be more specialized, the additional digit in the middle of the hand having been produced by the splitting of digit III. The longipinnate group would then be the more primitive and the latipinnate forms be derived from it by intercalation or splitting of digits.*

Strongly suggestive of the latipinnate and longipinnate paddles we find also in the Triassic genera a broad and a narrow type, the broad form occurring in *Mixosaurus*, the narrow form in all of the Californian genera. In the narrow type the limb is even more reduced than in the Longipinnati and is really tridactyle. So far as can be determined, *Toretocnemus* seems to be the most primitive of these forms. The rudimentary fourth digit is larger than in the others and the third digit is as large as the first. In *Delphinosaurus* the third digit is much smaller than the others and in *Shastasaurus osmonti* it was probably smaller than in *Delphinosaurus*. This series showing progressive reduction of the posterior side of the limb indicates that the type is probably not a primitive one, but is derived from an earlier form with five digits.

While we can understand the origin of the narrow type of paddle in the Trias, the broad form is not so easily explained if we hold that digit number one has disappeared. *Mixosaurus* had five digits of nearly equal size and made up largely of the shafted or primitive type of phalanges. The extremities of this form were, however, *already specialized paddles*, and, if the interpretation of the structure of the paddle of *Ichthyosaurus* given above is correct, we shall have to suppose that in this form digit I was lost and another digit added.

If finger I in *Mixosaurus* corresponds to primitive digit II, the added digit is either below the intermedium or on the posterior border of the limb. The presence of a supernumerary ossicle behind the carpus seems to give support to the idea that the last digit is not primitive, as elements of this character are known to develop secondarily, particularly on the posterior borders of the limbs of aquatic forms. Their presence does not prove the case, however. The supernumerary ossicle may be secondary and the digit primitive, or the presence of the ossicle may be due to upward movement of the last digit along the posterior side of the carpus. Such movements have occurred frequently in Ichthyosaurian paddles, regardless of the theory by which we account for them.

To suppose that one of the digits below the intermedium is f secondary origin would seem almost a violent assumption. That splitting and intercalation of digits have occurred in some f the broad-paddled Ichthyosaurs is beyond question, but evience of the character which we find in these forms is lacking in the paddle of *Mixosaurus*. The digits are of equal size nd their relations to the intermedium are such as one might xpect to find in a fairly primitive limb.

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* Mr. Lydekker has recently expressed himself as in accord with the views concerning the primitive character of the Mixosaurian paddle which are presented in this paper. See p. 29.

Though there is a tendency for the short first digit to disappear in the evolution of a natatory limb, it has not always done so, as for example in the Plesiosaurs. Farther, in the history of the Ichthyosauria two quite distinct types of paddles have appeared; the broad form, illustrated in the Latipinnati nd in *Mixosaurus;* and the narrow form, represented in the Longipinnati and in the Californian genera. In all probability he course of evolution has in all cases been fairly direct. That s, the broad paddles have tended toward greater width and he narrow ones toward slenderness. It is not easy to imagine hat after limbs had been reduced to a narrow type they would gain increase in width. There is therefore good reason to believe that *Mixosaurus* and the Latipinnati have retained the irst digit.

If the first digit in the limb of' *Mixosaurus* represents digit of a primitive pendactyle form, this type may be considered as the most generalized known in the Ichthyosauria. If, on the other hand, the first digit represents number two of the primitive form, the limb can hardly be considered as less pecialized than the tridactyle form seen in *Merriamia*, one orm having lost two digits, the other having lost one and gained one. Supporting the first suggestion we have the fact hat *Mixosaurus* is the oldest described form in which the imb structure is known. The beds in which it occurs are conidered by Fraas as the equivalent of some portion of the Middle Triassic, while the Californian genera belong to the Upper Triassic. Evidently *Mixosaurus* is the only described genus which could be considered as ancestral to the Jurassic orms. In the other genera the reduction of the digits has gone farther than in the Jurassic Longipinnati.

It is not impossible that other forms with wider paddles will be found in the American Trias, but up to the present time only the leptochirous or narrow-paddled group seems to be repesented. These forms may be closely related to the Longipinnati or may represent a branch of the order which diverged and pecialized early. The Longipinnati and Latipinnati may have developed from a persisting primitive stock after the American Triassic forms had become well separated from the est of the order.

It should be borne in mind that while the evidence furnished by limb structure is some of the most valuable material that we can obtain for use in working out the phylogeny of the Ichthyosaurs, it can hardly furnish the whole foundation for a definite classification. Inside the American group there seems to be considerable variation, though as yet we do not know all of the most important characters of these forms. *Toretocnemus* and *Merriamia* have very similar limbs but differ considerably in the structure of the vertebrae and ribs. It is perhaps a significant fact that of the several genera, *Toretocnemus*, with the largest vestigial fourth digit, appears in its general structure to be nearest to some of the earliest forms of Europe, represented by *Ichthyosaurus* (?) *atavus** from the lower portion of the middle Trias.

* Recent comparisons of *Ichthyosaurus* (?) *atavus* with the types of *Mixosaurus* show that most of the known vertebrae of *atavus* are quite different from those of the true Mixosaurs.. So far as is known, they appoach most nearly the type of the true Ichthyosaurs. They may belong to *Ichthyosaurus*, possibly to *Toretocnemus*, or may represent an undescribed genus.

University of California, Berkeley.

## Art. IV. — *The Interaction of Hydrochloric Acid and Potassium Permanganate in the Presence of Ferric Chloride;* by James Brown.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXXII.]

Löwenthal[*] and Lenssen were the first to show that the titration of ferrous salts by potassium permanganate in the presence of hydrochloric acid as proposed by Margueritte[†] does not admit of quantitative accuracy because of the evolution of chlorine by the interaction of hydrochloric acid and potassium permanganate, and to propose as a remedy for this source of error the titration of successive equal portions of the ferrous salt to be determined until the readings become constant.

This tendency toward evolution of chlorine in titrations of a ferrous salt by potassium permanganate in the presence of hydrochloric acid as compared with the alleged absence of such tendency in similar titrations of oxalic acid, was explained by Zimmermann[‡] on the supposition that the oxidation of the iron proceeds so rapidly as to form oxides of iron higher than the sesquioxide which then react to oxidize more iron and liberate chlorine from hydrochloric acid. Quite recently Wagner[§] explains this phenomenon by the assumed formation of chlor-ferrous acid (analogous to chlor-platinic and chlor-auric acids), which is more easily oxidized by the permanganate than is hydrochloric acid under similar conditions. Recent work[‖] has shown that there is a slight though real waste of permanganate in titrations of oxalic acid under the conditions named, and that this loss is proportional to the amount of hydrochloric acid present. It still appears, however, that this loss is greater in titrations of ferrous salts than in those of oxalic acid under the conditions named.

Wagner's work in relation to the phenomenon mentioned above has been reviewed very carefully, and it has been found that, although as shown by him more permanganate is required to bring about final coloration against equal quantities of oxalic acid in experiments in which equal quantities of potassium permanganate are digested with a constant quantity of normal hydrochloric acid and a measured volume of tenth normal ferric chloride than when an equivalent quantity of tenth-normal hydrochloric acid is substituted for the tenth-normal ferric chloride, the differences vary within wide limits and disappear entirely if the chlorine formed by the interaction of the potassium permanganate and hydrochloric acid is removed during the digestion. When also the chlorine is thus removed the same quantity of permanganate is required to bring about final coloration whether ferric chloride is present or not. It is found also that the permanganate is entirely destroyed within the limits proposed by Wagner, and that after an hour's digestion, and in fact long before, the permanganate color has entirely disappeared and only the hydrated oxides of manganese, formed according to the Guyard reaction, are visible in the digestion liquid.

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[*] Zeit. Anal. Chem., i, 329.

[†] Ann. Chim. [3], xviii, 244.

[‡] Ann. Chem., ccxiii, 311.

[§] Maassanalytische Studien, Habilitationsschrift, Leipzig, 1898.

[‖] Gooch and Peters: This Journal [4], vol. vii, 463.

Wagner describes no special form of apparatus in his work, and gives no details as to size of flask used to contain the digestion liquids, form of bath, etc., pointing out the fact simply that he used a return-condenser 60$^{cm}$ in length. It was found convenient in the experiments about to be described to use a 250$^{cm^3}$ flask to contain the solutions during digestion, and to heat the solutions in an Ostwald thermostat.

TABLE I.

[9·91$^{cm^3}$ $H_2C_2O_4$ = 20·25$^{cm^3}$ $KMnO_4$]

| $\frac{N}{1}$ HCl cm$^3$. | $\frac{N}{10}$ HCl cm$^3$. | $\frac{N}{10}$ $FeCl_3$ cm$^3$. | $KMnO_4$ before digestion. cm$^3$. | Temperature C°. | Time digestion. min. | $\frac{N}{10}$ $H_2C_2O_4$ cm$^3$. | $KMnO_4$ to color. cm$^3$. | $KMnO_4$ apparently reduced during digestion. cm$^3$. |
|---|---|---|---|---|---|---|---|---|
| 100 | 9·91 | --- | 9·91 | 50 | 60 | 9·91 | 15·89 | 5·55 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·11 | 4·77 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·15 | 4·81 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·07 | 4·73 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·13 | 4·79 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·07 | 4·73 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·08 | 4·74 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·02 | 4·68 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 14·85 | 4·51 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 14·40 | 4·06 |
| 100 | 9·91 | --- | 9·91 | “ | “ | 9·91 | 15·05 | 4·71 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·60 | 5·26 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·35 | 5·01 |
| 100 | --- | 9.91 | 9·91 | “ | “ | 9·91 | 15·32 | 4·98 |
| 100 | --- | 9.91 | 9·91 | “ | “ | 9·91 | 15·88 | 5·54 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·42 | 5·08 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·45 | 5·11 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·95 | 5·61 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·41 | 5·07 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·95 | 5·61 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 16·65 | 6·31 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·75 | 5·41 |
| 100 | --- | 9·91 | 9·91 | “ | “ | 9·91 | 15·79 | 5·45 |

The experiments of Table I were conducted, as outlined by Wagner, in the following manner: To a 250$^{cm^3}$ flask were added 100$^{cm^3}$ of normal hydrochloric acid (that is a solution contain-

36·4575 grams of the acid to the liter), and in addition either l$^{\text{cm}^3}$ of tenth normal hydrochloric acid (prepared by diluting $^{\text{cm}^3}$ of the normal solution to one liter) or 9·91$^{\text{cm}^3}$ of tenth mal ferric chloride. Of approximately twentieth normal ıssium permanganate, carefully standardized against ammo- ın oxalate, 9·91$^{\text{cm}^3}$ were then added, and the flask, fitted in a und joint to a return-condenser 60$^{\text{cm}}$ in length and with ore approximately 3$^{\text{cm}}$ in diameter, was heated for one r in the Ostwald thermostat at a temperature of 50° C. tenth normal oxalic acid, 9·91$^{\text{cm}^3}$ were then added to the estion liquid and a measured volume of the same perman- ate solution as was added before digestion was run in to color. difference between the total permanganate used (that is permanganate added before digestion plus that added to ıg about final coloration against the oxalic acid) and the manganate equivalent of the oxalic acid added gives, accord- to Wagner, the permanganate reduced during the diges- ı. The results of these experiments are recorded in the ve table.

lere it may be seen that although in general more perman- ate is required to bring about final coloration in those experi- ıts in which ferric chloride was used than in its absence, the ılts show at best wide variation among themselves, and the unts of permanganate apparently destroyed during the diges- ı are at all events considerably greater than in the experiments ducted by Wagner under similar conditions. In the experi- ıts recorded in Table I, in the average 4·73$^{\text{cm}^3}$ of per- ıganate were apparently destroyed where ferric chloride was used, and 5·37$^{\text{cm}^3}$ in the presence of ferric chloride; while Wagner's experiments 0·96$^{\text{cm}^3}$ of permanganate was appar- ly reduced without use of ferric chloride and 1·41$^{\text{cm}^3}$ in its sence.

ince, as has been noted above, the permanganate color irely disappeared in the experiments of Table I, long before termination of the hour's digestion, while only small amounts ıydrated oxides of manganese varying in color from brown lack were visible in the digestion liquid, it seemed probable t more permanganate was really reduced during the digestion n is indicated in these experiments. Moreover a strong r of chlorine was noticeable in these experiments and it ned probable that some of the chlorine, formed by the raction of the potassium permanganate and hydrochloric l during the digestion, remained to take part in the oxidation he oxalic acid introduced, and that, therefore, on running in manganate solution to color, less of the latter was required n corresponded to the oxalic acid left unoxidized by the dual oxides of manganese. It was, therefore, decided to remove if possible this chlorine, and to this end a vigorous current of carbon dioxide or air was passed through the digestion liquid while heating. In this way the chlorine was readily removed and starch and potassium iodide paper held in the current of carbon dioxide or air gave no test for chlorine.

The experiments of the following table (II), in which no ferric chloride was used, were conducted precisely as were those of Table I above, except that a vigorous current of carbon dioxide generated in a Kipp generator by action of hydrochloric acid on marble, and washed and dried by passing first through a bottle filled with water and then through a calcium chloride tube, was passed through the liquid during the process of digestion. Because also of the greater ease of measuring out accurately 9·90$^{cm^3}$ rather than the 9·91$^{cm^3}$ used by Wagner and in the experiments of Table I above, the former volume of reagents was substituted for the latter in the experiments to follow. It will readily be seen that in the case of tenth normal hydrochloric acid 0·01$^{cm^3}$ is negligible as compared with the large amount of hydrochloric acid used in the experiments.

The results of these experiments are recorded in Table II.

TABLE II.

| | $\frac{N}{1}$ HCl cm³. | $\frac{N}{10}$ HCl cm³. | $KMnO_4$ before digestion. cm³. | Temperature. C°. | Time of digestion. min. | $H_2C_2O_4$ cm³. | $KMnO_4$ to color cm³ | $KMnO_4$ apparently reduced during digestion. cm³. |
|---|---|---|---|---|---|---|---|---|
| [9·90$^{cm3}$ approximately $\frac{N}{10}$ $H_2C_2O_4$ =23·52 $^{cm3}$ $KMnO_4$] | | | | | | | | |
| I | 100 | 9·90 | 9·90 | 50 | 60 | 9·90 | 22·19 | 8·57 |
| II | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·10 | 8·48 |
| III | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·15 | 8·53 |
| IV | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·11 | 8·49 |
| [9·90$^{cm3}$ approximately $\frac{N}{10}$ $H_2C_2O_4$ = 23·65$^{cm3}$ $KMnO_4$] | | | | | | | | |
| V | 100 | 9·90 | 9·90 | 50 | 60 | 9·90 | 22·15 | 8·40 |
| VI | 100 | 9·90 | 9·90 | " | " | 9·90 | 21·79 | 8·04 |
| VII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·24 | 8·49 |
| VIII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·21 | 8·46 |
| IX | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·24 | 8·49 |
| X | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·23 | 8·48 |
| XI | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·25 | 8·50 |
| XII | 100 | 9·90 | 9·90 | " | " | 9·90 | 22·15 | 8·40 |
| XIII | 100 | 9·90 | 19·80 | " | " | 9·90 | 19·77 | 15·92 |
| XIV | 100 | 9·90 | 19·80 | " | " | 9·90 | 19·83 | 15·98 |
| XV | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·53 | 34·81 |
| XVI | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·47 | 34·75 |
| XVII | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·44 | 34·72 |
| XVIII | 100 | 9·90 | 50·0 | " | " | 25·00 | 44·58 | 34·86 |

From these results the conclusion may be drawn that the low indications of the amount of permanganate apparently reduced during digestion in the experiments recorded in Table I, at least so far as concerns those experiments in which no ferric chloride was used, were in all probability due to the oxidizing action of the unexpelled chlorine on the oxalic acid, and that the large variations in results were due to the greater or less retention of the chlorine. In experiments XIII to XVIII it is seen further that amounts of permanganate very much greater than those used in Wagner's experiments and in the experiments of Table I above can be reduced by the same amount of hydrochloric acid, and under the same conditions of temperature and time as in those other experiments; for, in these last experiments, also, the permanganate color entirely disappeared during the digestion.

In order to ascertain if a current of air is equally as effective in removing the chlorine as is carbon dioxide, and also because of the greater availability of the former, the experiments recorded in Table III were conducted in a manner identical with those of Table II, except that a current of air dried and purified was substituted for the carbon dioxide. When also the success of the air current was apparent, ferric chloride was again used and the effect noted.

Results are outlined in the following table.

TABLE III.

[9·90$^{cm^3}$ approximately $\frac{N}{10}$ $H_2C_2O_4$ = 20·09$^{cm^3}$ $KMnO_4$.]

| $\frac{N}{1}$ HCl cm³. | $\frac{N}{10}$ HCl cm³. | $\frac{N}{10}$ $FeCl_3$ cm³. | $KMnO_4$ before digestion. cm³. | Temperature. C°. | Time of digestion. min. | Residual $KMnO_4$ color after digestion. | Cl Test after digestion. | $H_2C_2O_4$ cm³. | $KMnO_4$ to color. cm³. | KMnO apparently reduced during digestion. cm³. |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 9·90 | ... | 9·90 | 50 | 60 | none | none | 9·90 | 18·88 | 8·69 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·87 | 8·68 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·80 | 8·61 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·80 | 8·61 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·82 | 8·63 |
| 100 | 9·90 | ... | 9·90 | " | 30 | " | " | 9·90 | 18·77 | 8·58 |
| 100 | 9·90 | ... | 9·90 | " | " | " | doubtful | 9·90 | 18·70 | 8·51 |
| 100 | 9·90 | ... | 9·90 | " | 15 | " | very faint | 9·90 | 18·70 | 8·51 |
| 100 | 9·90 | ... | 9·90 | " | " | " | " | 9·90 | 18·68 | 8·49 |
| 100 | ... | 9·90 | 9·90 | " | 60 | " | none | 9·90 | 18·87 | 8·68 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·85 | 8·66 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·81 | 8·62 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·87 | 8·68 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·85 | 8·66 |
| 100 | ... | 9·90 | 9·90 | " | 30 | " | " | 9·90 | 18·80 | 8·61 |
| 100 | ... | 9·90 | 9·90 | " | " | " | doubtful | 9·90 | 18·72 | 8·53 |
| 100 | ... | 9·90 | 9·90 | " | 15 | " | very faint | 9·90 | 18·65 | 8·48 |
| 100 | ... | 9·90 | 9·90 | " | " | " | " | 9·90 | 18·67 | 8·48 |

Here again may be noted the concordance of results when the chlorine is all removed before the addition of oxalic acid, as well as the fact that under these conditions substantially the same amount of permanganate is required to bring about the end reaction, whether ferric chloride is present or not; and that consequently as much permanganate is reduced during the digestion in the latter case as in the former. Also by a comparison of experiments VIII–X and XVIII–XX, in which a slight trace of chlorine remained, with experiments I–VI and XI–XVI, in which the chlorine was entirely removed, we again see the oxidizing effect of the residual chlorine on the oxalic acid; for even in the former sets of experiments, in which the digestion was carried on only fifteen or thirty minutes, the permanganate color had entirely disappeared at the end of the digestion. The variations in the amount of permanganate apparently reduced during the digestion in the experiments recorded in Table I are, therefore, doubtless due to the interfering action of the residual chlorine held in solution. The "$KMnO_4$ apparently reduced during digestion" in the experiments of Table II, and in those of Table III in which the chlorine was entirely removed during the digestion, represents the amounts of permanganate entirely reduced to manganous chloride, while the differences between these amounts and the "$KMnO_4$ before digestion" represent the residual oxides of manganese. Similar differences in the experiments of Table I, and in those of Table III in which the chlorine was only partially removed, represent the residual oxides of manganese and the chlorine retained in solution.

The amount of chlorine held in solution when no means are employed to remove it, depends largely on the form and size of the flask used to contain the solutions during digestion, also on the dimensions of the return-condenser, and will vary according to the greater or less amount of shaking to which the flask is subjected during the entire course of the experiment. It is, therefore, evident that Wagner's experiments are in no way indicative of the relative amounts of potassium permanganate reduced in the presence or absence of ferric chloride other conditions being constant, but are an indication simply of the greater or less retention of chlorine in solution in the form of apparatus used by him; for it has been shown that in all experiments conducted within the limits proposed by Wagner the permanganate is entirely destroyed and that any variations in the amount of permanganate apparently destroyed during digestion disappear when the chlorine is entirely removed from the sphere of action. The possibility of any interfering action of ferric chloride in titrations of oxalic acid by potassium permanganate is excluded by the results of the experiments of

Table III, in which we find no variations in results whether ferric chloride is present or not. The cause of the apparently greater destruction of potassium permanganate in those experiments of Table I in which ferric chloride was used than in those in which ferric chloride was not used, is now under investigation.

TABLE IV.

| $\frac{N}{1}$ HCl cm³. | $\frac{N}{10}$ HCl cm³. | $KMnO_4$ before digestion. cm³. | $H_2O$ cm³. | Volume during digestion. cm³. | Temperature. C°. | Time of digestion min. | Residual $KMnO_4$ color after digestion. | Cl test after digestion. | $H_2C_2O_4$ cm³. | $KMnO_4$ to color. cm³. | $KMnO_4$ apparently reduced during digestion. cm³. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [40$^{cm^3}$ $\frac{N}{10}$ $(H_4N)_2C_2O_4$ = 37·64$^{cm^3}$ $KMnO_4$<br>100$^{cm^3}$ $H_2C_2O_4$ = 101·40$^{cm^3}$ $KMnO_4$] | | | | | | | | | | | |
| 100 | 9·90 | 100 | .. | 210 | 50 | 60 | none | faint | 100 | 59·52 | 58·12 |
| 100 | 9·90 | 100 | .. | 210 | “ | “ | “ | “ | 100 | 58·44 | 57·04 |
| [40$^{cm^3}$ $\frac{N}{10}$ $(H_4N)_2C_2O_4$ = 18·35$^{cm^3}$ $KMnO_4$<br>50$^{cm^3}$ $\frac{N}{5}$ $H_2C_2O_4$ = 49·26$^{cm^3}$ $KMnO_4$.] | | | | | | | | | | | |
| 100 | 9·90 | 50 | .. | 160 | 50 | 60 | none | none | 50 | 30·72 | 31·46 |
| 100 | 9·90 | 50 | .. | 160 | “ | “ | “ | “ | 50 | 30·75 | 31·49 |
| 100 | 9·90 | 50 | .. | 160 | “ | “ | “ | “ | 50 | 30·76 | 31·50 |
| 100 | 9·90 | 50 | .. | 160 | “ | “ | “ | “ | 50 | 30·78 | 31·52 |
| 100 | 9·90 | 50 | .. | 160 | “ | “ | “ | “ | 50 | 30·88 | 31·62 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | faint | faint | 50 | 27·11 | 27·85 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 27·92 | 28·66 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 28·52 | 29·26 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 28·54 | 29·28 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 29·14 | 29·88 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 28·98 | 29·72 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 28·56 | 29·30 |
| 100 | 9·90 | 50 | 50 | 210 | “ | “ | “ | “ | 50 | 29·96 | 30·70 |
| 100 | 9·90 | 50 | 50 | 210 | “ | 85 | none | very faint | 50 | 29·96 | 30·70 |
| 100 | 9·90 | 50 | 50 | 210 | “ | 60 | faint | faint | 50 | 30·22 | 30·96 |
| 100 | 9·90 | 75 | .. | 185 | “ | “ | none | marked | 50 | 20·72 | 46·46 |
| 100 | 9·90 | 50 | 50 | 210 | “ | 120 | none | none | 50 | 30·31 | 31·05 |
| 100 | 9·90 | 100 | .. | 210 | “ | 60 | marked | marked | 60 | 19·58 | 60·47 |
| 100 | 9·90 | 75 | 50 | 235 | “ | 220 | none | faint | 50 | 21·84 | 47·58 |
| 100 | 9·90 | 100 | 50 | 260 | “ | 180 | marked | marked | 60 | 10·18 | 51·07 |
| $\frac{2N}{1}$ HCl | | | | | | | | | | | |
| 50 | 9·90 | 50 | .. | 110 | “ | 60 | none | faint | 50 | 30·23 | 30·97 |
| 50 | 9·90 | 75 | .. | 135 | “ | 60 | “ | marked | .. | .. | .. |
| 50 | 9·90 | 75 | .. | 135 | “ | 60 | “ | “ | 50 | 30·69 | 56·43 |

Since in all experiments thus far conducted the permanganate color has been entirely destroyed, the experiments of Table IV were made to ascertain if possible how much permanganate can be destroyed by the amount of hydrochloric acid used in the experiments of Table I, II, and III, under the same conditions of time and temperature, and also during greater periods of time. It will readily be seen from the evident oxidation of oxalic acid by chlorine in previous experiments that an exact measure of the maximum amount of permanganate reduction during a given period of time can be obtained only when all the chlorine is removed and at the same time the permanganate color just disappears—a condition difficult to attain. The results recorded in Table IV should therefore be regarded as approximate only.

Thus it may be seen that the same amount of hydrochloric acid as was used in the experiments of Table I, II, and III is capable of breaking down approximately thirty times as much permanganate as was used in those experiments and in the experiments of Wagner, conditions of time and temperature being the same. Changes of volume are of course involved in the use of varying amounts of permanganate but an increase in volume would in all probability be attended by a decrease in the relative amount of permanganate reduced by a constant quantity of hydrochloric acid. In any case the results show a more extensive reduction than is indicated in Wagner's experiments and in those of Tables I, II, and III above.

The conclusion must be drawn, then, that Wagner's experiments in no way show the catalytic effect of ferric chloride in the interaction between hydrochloric acid and potassium permanganate, nor do they furnish evidence in support of the assumed formation of chlor-ferrous acid. They afford simply an indication of the greater or less retention of chlorine in solution, and the greater or less oxidizing action of this chlorine on the oxalic acid in the presence or absence of ferric chloride.

The author is indebted to Prof. F. A. Gooch for much advice and assistance in the preparation of this paper.

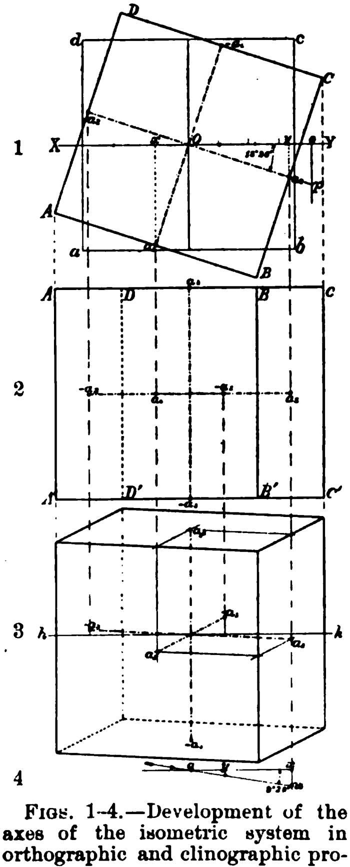
## ART. V.—*On Crystal Drawing;* by S. L. PENFIELD.

*Introduction.*—The methods commonly employed for representing crystals consist in drawing their edges as they appear when projected upon a plane. A peculiarity of the methods used is that the eye, or point of vision, is regarded as being at an infinite distance from the object, so that all edges which are parallel on a crystal appear as parallel lines in the drawing. Thus true perspective, whereby parallel edges would appear in a drawing as lines approaching one another in the distance, is lost sight of. Furthermore, two kinds of projection are employed: *orthographic*, where the lines of projection fall at right angles, and *clinographic*, where they fall at an oblique angle on the plane upon which the drawing is made. Most of the figures found in works on mineralogy and crystallography are drawn in clinographic projection.

The data generally employed in constructing a crystal figure are the inclinations and lengths of the axes and the symbols of the forms, while interfacial angles are not made use of directly, other than as they may have been employed for determining the axial relations and the symbols of the several faces.

To be really successful in drawing, it is essential that one should have a thorough understanding of the form or combination to be represented, and that every step in the process of constructing a figure should be fully comprehended. The reason for offering the present communication is the hope entertained by the writer, that by developing the subject of crystal drawing in a manner somewhat different from that generally adopted, the processes involved may be comprehended more readily and the work accomplished with greater facility and accuracy.

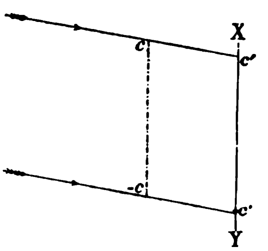
*Projection of the Axes of the Isometric System.*—It is believed that figures 1 to 4 will make clear the principles upon which the projection of the isometric axes are based. Figure 1 is an orthographic projection (a *plan*, as seen from above) of a cube in two positions, one, *a b c d*, in what may be called normal position, the other, *A B C D*, after a revolution of 18° 26′ about its vertical axis. The broken-dashed lines throughout represent the axes. Figure 2 is likewise an orthographic projection of a cube in the position *A B C D* of figure 1, when viewed from in front, the eye or point of vision being on a level with the crystal. In the position chosen, the apparent width of the side face *B C B′ C′* is one-third that of the front face *A B A′ B′*, this being dependent upon the angle of revolution 18° 26′, the tangent of which is equal to $\frac{1}{3}$. To construct the angle 18° 26′, draw a perpendicular at any point on the horizontal line, as at *o* figure 1, make *op* equal one-third *Oo*, and join *O* and *p*. The next step in the construction is a change from orthographic to clinographic projection. In order to give figures the appearance of solidity it is supposed that the eye or point of vision is raised, so that one looks down at an angle upon a crystal which is figured; thus, in the case under consideration, figure 3, the top face of the cube comes into view. The position of the crystal, however, is not changed, and the plane upon which the projection is made remains vertical. From figure 1 it may be seen that the positive ends of the axes $a_1$ and $a_2$ are forward of the line *XY*, the distances $a_1 x$ and $a_2 y$ being as 3:1. In figure 2 it must be imagined, and by the aid of a model it may easily be seen, that the extremities of these same axes are to the front of an imaginary vertical plane (the projection of *XY* above) passing through the center of the crystal, the distance being the same as $a_1 x$ and $a_2 y$ of the plan. In figure 4 the distance *ax* is drawn of the same length as $a_1 x$ of the plan, and the amount to which it is supposed that the eye is raised, indicated by the arrow, is such that *a*, instead of being projected horizontally to *x*, is projected at an inclination of 9° 28′ from the horizontal to *w*, the distance *xw* being one-sixth of *ax*; hence the angle 9° 28′ is such that its tangent is $\frac{1}{6}$. Looking down upon a solid at an angle, and still making the projection on a vertical plane, may be designated as *clinographic projection;* accordingly, to plot the axes of a cube in clinographic projection in conformity with figures 1, 2 and 4, draw the horizontal construction line *hk*, figure 3, and cross it by four perpendiculars in vertical alignment with the points $a_1, -a_1$ and $a_2, -a_2$ of figures 1 and 2. Then determine the



Figs. 1–4.—Development of the axes of the isometric system in orthographic and clinographic projection.

extremities of the first, $a_1$, $-a_1$ axis by laying off distances equal to *xw* of figure 4, or one-sixth $a_1\,x$ of figure 1, locating them below and above the horizontal line *hk*. The line $a_1$, $-a_1$ is thus the projection of the first, or front-to-back axis. In like manner determine the extremities of the second axis, $a_2$, $-a_2$, by laying off distances equal to one-third *xw* of figure 4, or one-sixth $a_2\,y$ of figure 1, plotted below and above the line *hk*. The line $a_2$, $-a_2$ is thus the projection of the second, or right-to-left axis. It is important to keep in mind that in clinographic projection there is no foreshortening of vertical distances. This is evident from figure 5, where *c*, $-c$ is supposed to represent a vertical axis and *XY* the trace of a vertical plane on which the projection is made. The parallel lines of sight, indicated by the arrows, project the axis *c*, $-c$ to $c'$, $-c'$ without change of length. In figure 3 the axis $a_2$, $-a_2$ is somewhat, and $a_1$, $-a_1$ much foreshortened, yet both represent axes of the same length as the vertical, $a_2$, $-a_2$, and of the plan above, when plotted in clinographic projection. The completion of the cube about the clinographic axes, as indicated by the construction lines, figure 3, is too simple to need special comment.

5



It is wholly a matter of choice that the angle of revolution shown in figure 1 is 18° 26′, and that the eye is raised so as to look down upon a crystal at an angle of 9° 28′ from the horizontal, as indicated by figure 4. Also it is evident that these angles may be varied to suit any special requirement. As a matter of fact, however, the angles 18° 26′ and 9° 28′ have been well chosen and are established by long usage, and practically all of the figures in clinographic projection, found in modern treatises on crystallography and mineralogy, have been drawn in accordance with them. The development of the axes as indicated by figures 1 to 4 yields the same result as that obtained from following the scheme found in almost all textbooks of crystallography, accredited to Naumann.*

It will be observed that figures 1 and 3 are in vertical alignment, and one of the chief features of this communication will be to emphasize the value and importance of two projections, orthographic and clinographic. The object of the upper figure or *plan* is twofold: (1) it may be employed as a help in the construction of the more complex clinographic projection below, and (2) it serves to make clear certain relations which at times are only with difficulty, if at all, comprehended from a clinographic projection alone. Figures 2 and 4 have been introduced merely as helps in the development of the clinographic projection. It is also worthy of note that in the majority of cases a plan and its accompanying clinographic projection may be drawn more readily than a single figure in clinographic projection alone.

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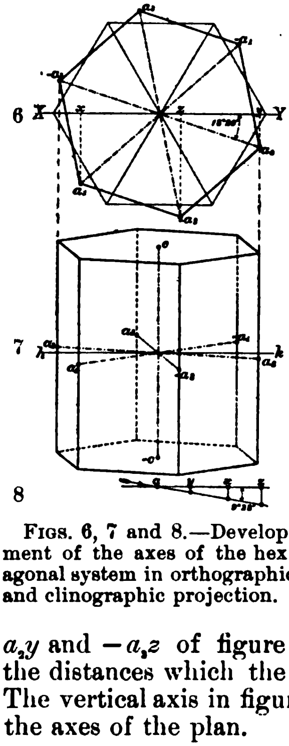
* Lehrbuch der Krystallographie, 1830, Band II, p. 400.

No originality is claimed for the idea of making use of a plan in connection with a clinographic projection. The principles are those commonly made use of in mechanical drawing, though generally in dealing with that subject orthographic projection alone is employed. In Kokscharow's Atlas accompanying his "Mineralogie Russlands" it will be found that a plan accompanies almost every figure drawn in clinographic projection, while Miller in his "Treatise on Mineralogy" employs orthographic projection almost exclusively. Lastly, students of crystallography may use an orthographic and its accompanying clinographic projection much as a carpenter or builder uses a plan and its accompanying elevation. The one supplements the other.



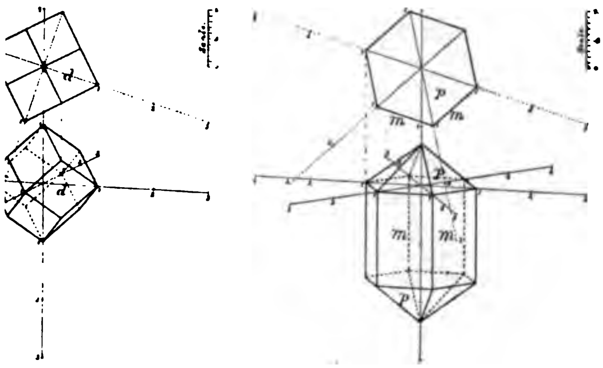
FIGS. 6, 7 and 8.—Development of the axes of the hexagonal system in orthographic and clinographic projection.

*Projection of the Axes of the Hexagonal System.*—For projecting the hexagonal axes exactly the same principles may be made use of as were employed in the construction of the isometric axes. Figure 6 is an orthographic projection, *a plan*, of a hexagonal prism in two positions, one of them, $a_1$, $a_2$, etc., after a revolution of 18° 26′ from what may be called normal position. In figure 7 the extremities of the horizontal axes of figure 6 have been projected down upon the horizontal construction line *hk*, and $a_1$, $a_2$ and $-a_3$ which are forward of the line *XY* in figure 6 are located below the line *hk* in the clinographic projection, the distances from *hk* being one-sixth of $a_1x$, $a_2y$ and $-a_3z$ of figure 6. Figure 8 is a scheme for getting the distances which the extremities of the axes are dropped. The vertical axis in figure 7 has been given the same length as the axes of the plan.

*Axes.*—For the purpose of facilitating crystal writer has had the isometric and hexagonal axes ıd impressions of them made on good quality of ›er have been found very useful. To insure accu- ʳere plotted on a large scale (the vertical axis $28^{cm}$ ıd they are shown very much reduced in figures 9 .ch axis from the center is divided into thirds, and e lengths marked 1, when taken as *unity*, will give onvenient size for drawing. In figure 9 an ortho- a clinographic projection of a dodecahedron are in figure 10 corresponding projections of a combi- ism *m* and pyramid *p* of apatite, $c = 0{\cdot}735$. As is ı the figures, the upper axes are for orthographic,

9

10



0.—Scheme of the engraved axes of the isometric and hexagonal systems, one-sixth natural size.

or clinographic projections. The sections of the 1 *2* and *3* are lengths most frequently needed in tion of complex figures. Printed on each sheet is h will be referred to as the *scale of decimal parts.* equal to that of *unity* on both the vertical axis › for orthographic projection. As printed on the ›ts the scale is divided into one hundred parts.

*the Tetragonal and Orthorhombic Systems.*—For ragonal and orthorhombic crystals the engraved ɛes may be used, after changing certain lengths. axis for both systems is changed by taking the ₂th from the scale of decimal parts, referred to ious paragraph. For an orthorhombic crystal the ıe brachy, or *ă*, axis is first laid off on the front-to-back axis of the orthographic projection above by means of the scale of decimal parts, and is then projected down upon the front-to-back axis below by means of a vertical line. Thus with facility and accuracy the engraved isometric axes may be modified to suit the requirements of any tetragonal or orthorhombic crystal.

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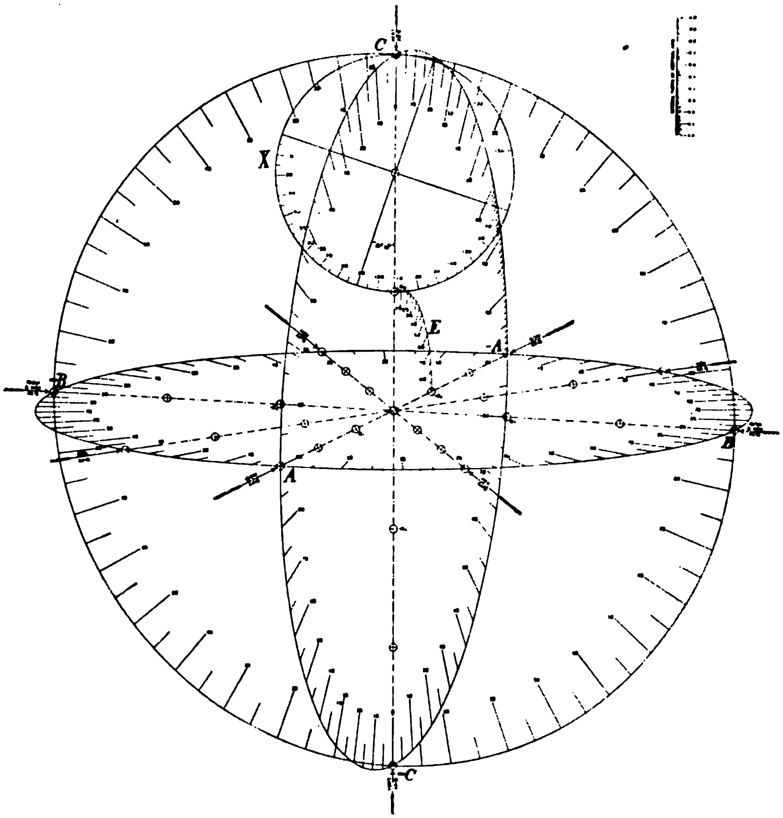

FIG. 11.—Protractor for plotting crystallographic axes; one-third natural size.

*Projection of the Axes of the Monoclinic and Triclinic Systems.*—These axes are obtained from those of the isometric system by giving the lines suitable inclinations, and varying their lengths. Instead, however, of using the methods generally employed for inclining the axes, it occurred to the writer that both time and accuracy might be gained by constructing a suitable protractor, which is shown one-third its natural size in figure 11. At the top is a graduated circle, *X*, two of the diameters of which inclined at 18° 26′ to the vertical and horizontal, represent unit lengths of the *a* and *b* axes in orthographic projection. The uses of the circle and its graduation will be explained later. The three large ellipses are the clinographic projections of three circles uniting the ends of the isometric *A*, −*A*; *B*, −*B* and *C*, −*C* axes; they represent, therefore, the paths which the extremities of the axes would follow if the latter were revolved in the three axial planes. The ellipses may also be regarded as the clinographic projection of three great circles of a sphere; an equator, crossed by two meridians at 90° to one another. The ellipses and their graduation were plotted with much care, and the engraving was skillfully executed by Messrs. Bormay & Co. of New York. Each axis is divided into thirds, and a scale giving decimal parts of the vertical axis accompanies the protractor. The quadrant of a small ellipse *E* has a radius equal to one-third that of the large ellipse. It is intended for getting one-third the length of an inclined *a* axis, but it has not proved to be of much value. Printed on cardboard, the protractor may be used for a long time, it being intended that the axes shall be transferred to a sheet of drawing paper by superimposing the protractor and puncturing the unit lengths of the axes with a needle point.

The axial protractor has been in use in the writer's laboratory for four years, and has been found very convenient, not only for plotting axes of the monoclinic and triclinic systems, but, also, for constructing the axes of twin crystals. It may be said of the protractor and also of the engraved axes that they have proved to be not only time-savers, but they have also helped to make the work of crystal drawing more accurate and better understood. Students frequently encounter difficulties in crystal drawing because the axes with which they are working have not been plotted with accuracy, but by the use of the engraved axes this difficulty, at least, is eliminated.

A few examples will serve to illustrate the methods of using the axial protractor in plotting inclined axes.

In both the monoclinic and triclinic systems the same method is used for plotting the *a* axis at the inclination $\beta$, hence one example in the triclinic system will serve for the two classes of crystals. The example chosen is rhodonite, and the data needed are as follows:

$$a : b : c = 1{\cdot}073 : 1 : 0{\cdot}621$$
$$\alpha = 103^\circ\ 18'; \ \beta = 108^\circ\ 44'.$$
$$a \wedge b,\ 100 \wedge 010 = 94^\circ\ 26'.$$

The projection of the *a* axis, which is the same for both the monoclinic and triclinic systems, will first be explained: When *a* is not at right angles to *c*, it must appear somewhat foreshortened in orthographic projection, as shown in figure 12, which represents the relations of the *a* and *c* axes of rhodonite: *XY* being the trace of the horizontal plane on which the orthographic projection is made, the *a* axis, length 1·073, will appear foreshortened to the length *Oa'*. Applying the foregoing principle to the upper circle of the protractor,* figure 13, draw a radius at the inclination *β*, 108° 44', making use of the graduation of the circle, lay off on this

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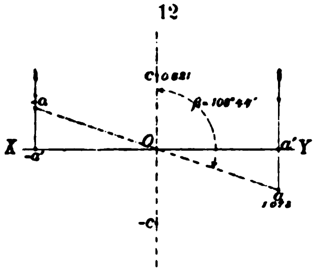

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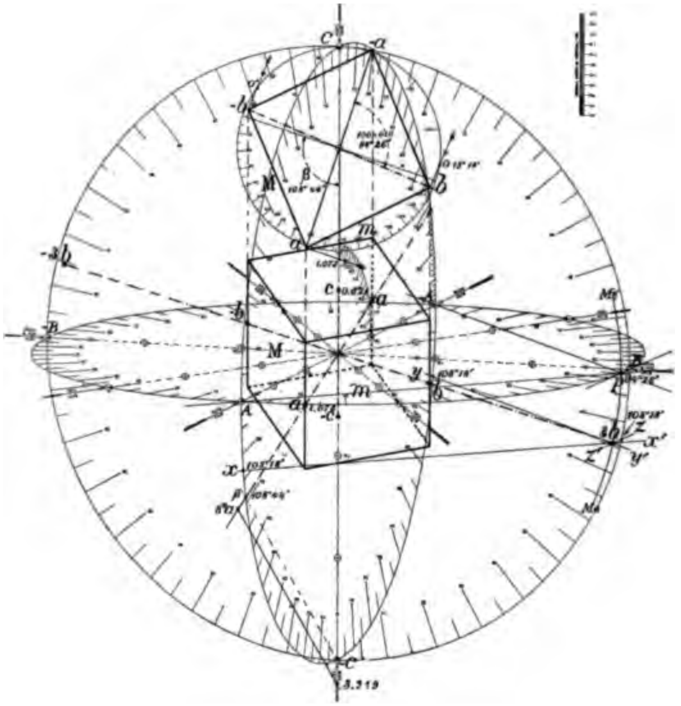

radius the length of the *a* axis (1·073 in figure 13) using the scale of decimal parts, and then project at right angles to the direction *a*, −*a*, as indicated by the arrow, thus determining the length of the foreshortened *a* axis. For the clinographic projection locate $\beta$, 108° 44′, on the graduation of the ellipse passing through *A* and *C*, draw a diameter through the center and fix the length of *a* by projecting down vertically from *a* of the orthographic axis above. If one does not wish to make use of the orthographic axes, draw the diameter of the ellipse at the inclination $\beta$, and find the length $3a$ by laying off a distance equal to $3a$ on the vertical axis (3·219 in figure 13), using the scale of decimal parts, and then transpose the length thus found to the inclined *a* axis by drawing a line parallel to $\beta$, $-C$, as shown in the figure: One-third of the length thus determined is the desired length of the *a* axis.

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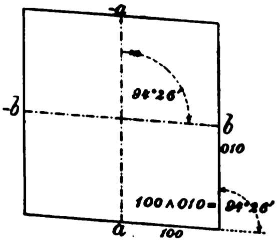

Two processes are involved in plotting the *b* axis of a triclinic crystal. (1) The vertical plane in which the *b* and *c* axes are located is revolved about the *c* axis so as to conform to the measurement $a \wedge b$, $100 \wedge 010$. Care must be taken to note the direction in which the plane of the *b* and *c* axes is turned: (1) As shown in figure 14, since $100 \wedge 010$ (angle between normals) is 94° 26′ in rhodonite, the right-hand end of the *b* axis is first swung forward 4° 26′ in the plane of the equator. Carrying out the foregoing process in figure 13, a point *p* is located on the equator, 94° 26′, measured from $-A$, and likewise *b* of the orthographic projection above is brought forward to a position 94° 26′ from $-a$. (2) The horizontal *b* axis, in its new position, must next be inclined to the vertical axis at the angle $\alpha$, which in rhodonite is 103° 18′. For the orthographic projection above, this inclination of the *b* axis causes some foreshortening, which is determined by laying off two points *o* and *o′*, figure 13, 13° 18′ (103° 18′ −90°) on either side of where the *b* axis intersects the divided circle, and projecting through the points thus formed at right angles to the direction *b*, $-b$, as indicated by the arrows. To give the *b* axis of the clinographic projection its proper inclination, the value of $\alpha$, 103° 18′, is laid off on two, or preferably three, of the vertical ellipses, as at *x*, *y* and *z*, figure 13, measured from *C*. Next draw three chords, *Ap*, $-Ap$ and *Bp*, on the plane of the equator, and parallel to them, respectively, the chords *xx′*, *yy′* and *zz′*. The common intersection of the three chords determine a point $3b$, on the surface of an imaginary sphere and on a meridian *Me* passing through *p*. The point $3b$ is 13° 18′ below the equator and 103° 18′, that is $\alpha$, from *C*. A line from $3b$ through the center is the projection of the *b* axis, and a perpendicular from *b* of the orthographic projection above will intersect the axis at one-third of its length.

The principle involved in the projection of the clinographic *b* axis, as given above, is very simple. Imagine a sphere with two points fixed on its equator corresponding to *A* and *p* of figure 13, and then a chord *Ap* through the two points; it then follows that a series of chords parallel to *Ap* drawn through the 5°, 10°, 15°, etc., graduation points of the meridian through *A* would all emerge from the imaginary sphere on a meridian *Me*, figure 13, passing through *p*, at points 5°, 10°, 15°, etc., from the equator. By drawing two chords, *xx′* and *yy′*, as in figure 13, or a third *zz′* so as to make more certain of the intersection, any desired point on the meridian through *p* is quickly found. In figure 13 a combination of the prisms *m* (110) and *M* $(1\bar{1}0)$ and the base *c* (001) has been drawn.

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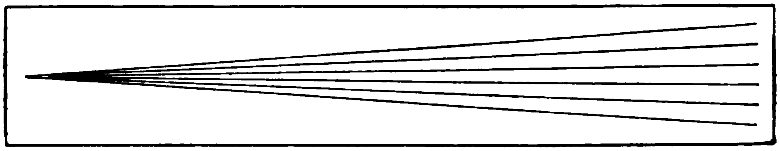

It may be said concerning the protractor that it has been plotted on a large scale to insure accuracy, and that lengths corresponding to one-third those of the axes will generally be found convenient for drawing simple crystal figures. In connection with the protractor it is recommended to use a scale, corresponding to figure 15, printed or drawn on tracing cloth or paper. When the outer lines of such a scale are adjusted between the five degree graduation marks of the ellipses, the intermediate lines will serve to subdivide the space into fifths, or degrees.

*Projection of the Axes of twinned Crystals.*—The axial protractor furnishes a ready means for plotting the axes of twin crystals, a problem which at times presents considerable difficulty, especially to beginners, hence two examples may be cited explaining the uses of the protractor. In staurolite, twins according to a pyramid are common, and in the example chosen it will be assumed that a face having the symbol $\bar{2}3\bar{2}$ $(-\frac{3}{2}a : b : -\frac{3}{2}c)$ is the twinning plane. The data employed in plotting the axes are the axial lengths, $a : b : c = 0{\cdot}473 : 1 : 0{\cdot}683$, and the $\phi$ and $\rho$ angles of the twinning plane; $\phi = 010 \wedge \bar{2}30 = 54°\ 37'$ and $\rho = 00\bar{1} \wedge \bar{2}3\bar{2} = 60°\ 31'$. To insure accuracy in plotting, the full lengths of the axes of the protractor have been regarded as unity. In figure 16 the axial lengths $-a$ and

$-\frac{3}{2}a$; $b$; and $-c$, and $-\frac{3}{2}c$ are laid off both on the orthographic and clinographic projections of the axes, and the twinning plane $-\frac{3}{2}a : b : -\frac{3}{2}c$ drawn. The value of $\phi$, 54° 37′, is laid off at *p* on the equator, measuring in the direction of the arrow from *b*, and the radius from the center *O* to *p* makes an angle of 90° at *P* with the line $-\frac{3}{2}a : b$. The twinning axis, a line

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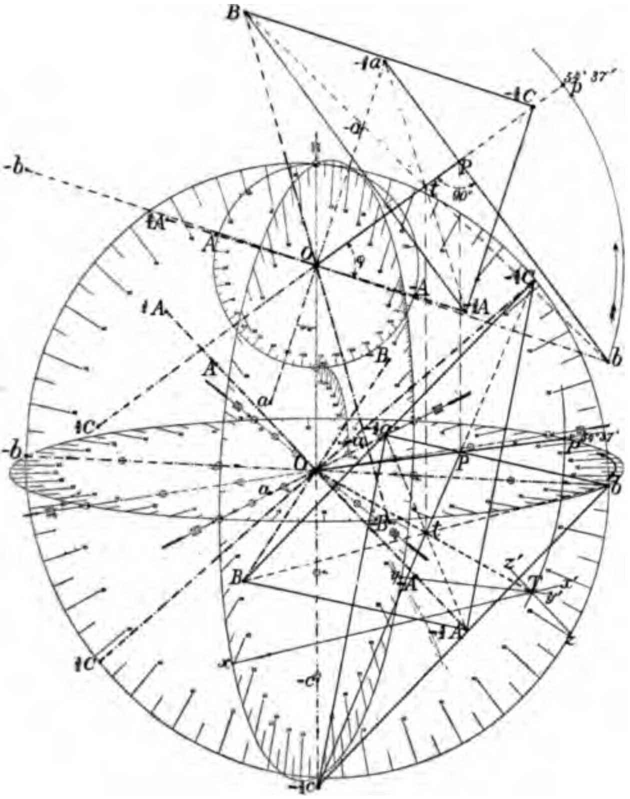

from the centre at right angles to the twinning plane, is now plotted on the clinographic axes by finding a point *T*, on the meridian through *p*, 60° 31′ (the value of $\rho$) from the south pole of an imaginary sphere. This is done by locating *x*, *y* and *z* on the graduated ellipses at 60° 31′ from the south pole, and drawing the chords *xx′*, *yy′* and *zz′* parallel, respectively, to chords on the plane of the equator through *p* and the intersections of the *a* and *b* axes with the equator. The intersection of the three chords determine the desired point *T* at the surface of an imaginary sphere on the meridian through *p*, and *OT* is the twinning axis. The point *t*, where the twinning axis pierces the twinning plane, is determined by the intersection of the twinning axis *OT* with a line drawn from $-\frac{3}{2}c$ to *P*. The points *p*, *P* and *t* of the orthographic projection are in vertical alignment with corresponding points on the lower axes, and need no further explanation. Having found *t* on both the clinographic and orthographic axes, the ends of the axes, $-\frac{3}{2}a$, *b* and $-\frac{3}{2}c$, are shifted respectively to $-\frac{3}{2}A$, *B* and $-\frac{3}{2}C$, equidistant from *t*, as would result from a revolution of 180° about the twinning axis. Lines from the centers of the two projections through $-\frac{3}{2}A$, *B* and $-\frac{3}{2}C$ are the axes in twin position. In figure 17 the axes are shown without construction lines, *a* and *b* being one-third as long as in figure 16, and in figure 18 two projections of interpenetrating prisms, *m*, terminated by basal planes, *c*, are shown.

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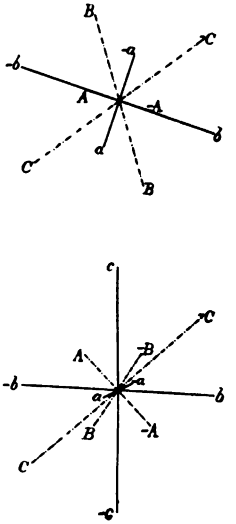

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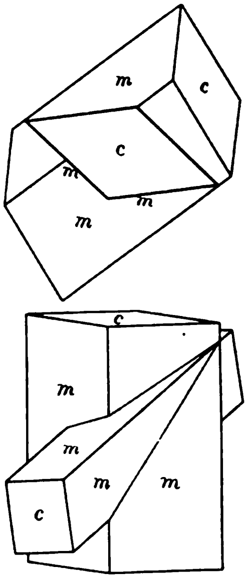

A problem encountered by W. E. Ford and the writer in the study of twin crystals of calcite from Union Springs, N. Y.,* may be cited as a second example for illustrating the uses of the axial protractor in plotting the axes of twin crystals. It was desired to represent a scalenohedron, twinned about the rhombohedron *f* ($02\bar{2}1$), so drawn that the twinning plane should be vertical and have the position corresponding to that of the side pinacoid *b* (010) of an orthorhombic crystal. The solution depends upon the angle of base on twinning plane, $c \wedge f = 63° 7'$, from which the inclination of the vertical axes, 53° 46′ from one another, or 26° 53′ from the twinning plane placed in vertical position, as shown in figure 19, is derived. As indicated by figure 20, the inclinations of the vertical axes, *c* and *C*, 26° 53′, from the perpendicular, are determined by the graduation of the vertical ellipse through *B*. Also the intersections of the planes of the horizontal axes with the same ellipse are located at *X* and *X′*, and *Y* and *Y′*, 26° 53′ from *B* and $-B$. In order to have the twinning plane correspond with the side pinacoid 010 of the orthorhombic system, it is necessary to make one of the horizontal axes $-a_3$, $a_3$ of the hexagonal system correspond with the front and back or *a* axis of the orthorhombic system. The

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* This Journal (4), x, p. 237, 1900.

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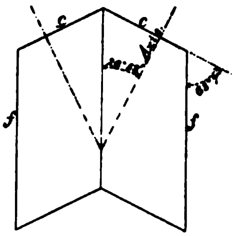

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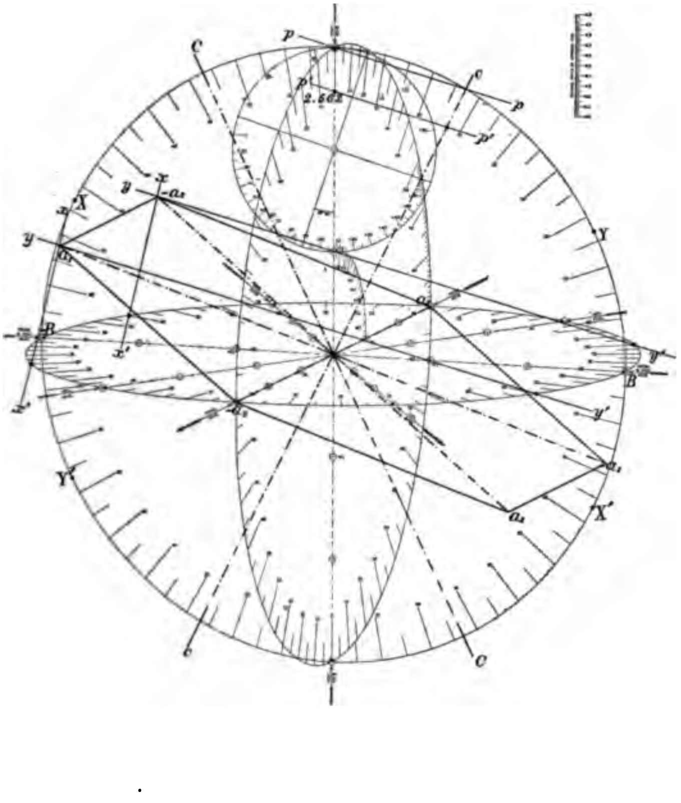

other hexagonal axes, therefore, must intersect great circles passing through $-a_3$ and $X$, and $-a_3$ and $Y$, at 60° from $-a_3$ and $a_2$. To find the desired intersections on the great circle at right angles to one of the twinned axes, $c$; through the 60° graduation points on the horizontal ellipse to the left, figure 20, draw the chords $xx'$ parallel to a chord through $-B$ and $X$; likewise through the 60° points on the horizontal ellipse to the right draw the chords $yy'$ parallel to a chord through $B$ and $X$. The intersections of the chords $xx'$ and $yy'$ determine the extremities of the horizontal axes $a_1$, $-a_1$, and $a_2$, $-a_2$. To make the drawing somewhat more real, a hexagon at right angles to the twin axis $cc$ has been constructed, by uniting the ends of the horizontal axes. Following a similar process (drawing chords parallel to $BY$ and $-BY$ through the 60° graduation points of the horizontal ellipse) the extremities of the horizontal axes at right angles to the twinned axis $C$ would be found, but it has not seemed best to complicate the figure by carrying out this construction. The length of the vertical axis of calcite is 0·854, and this is plotted on the vertical axis by laying off three times 0·854 (2·562) on the perpendicular, using the scale of decimal parts, and proportioning the length on the twinned $c$ axis by constructing the parallel lines $pp$ and $p'p'$, as indicated in figure 20. Figure 21 represents the scalenohedron $v$ $\{21\bar{3}1\}$ of calcite drawn on the twinned axes, and figure 22 is a development like that observed on the crystals from Union Springs, N. Y., where the re-entrant angle is obliterated by the extension of four of the faces, resulting in a peculiar spear-head shaped development.

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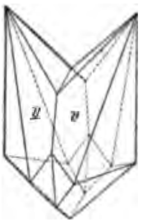

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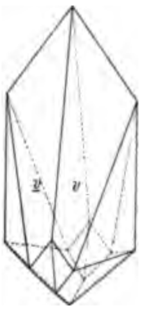

*Use of T-square and special Triangles.*—A T-square may be used to advantage in connection with the engraved axes, figures 9 and 10, the paper *PP*, figure 23, being adjusted on a drawing board *BB* so that the blade of the T-square is parallel with the right-to-left or $b$ axis of the clinographic projection. If an ordinary rectangular drawing board is used, the paper may be fastened somewhat askew upon it, and it is not at all necessary to have a board with its right-hand edge cut at a special angle, as shown in figure 23. Special triangles have also proved to be very convenient. One of these is a truncated triangle $I$, figure 23, so made that when its lower edge is against the blade of the T-square its upper edge is parallel to the right-to-left of *b* axis, and its left-hand edge parallel to the front-to-back or *a* axis of the orthographic projection. A second triangle *II* is shown in two positions in figure 23; II*a*, when its shorter edge is against the blade of the T-square its right-hand edge is parallel to the vertical axis, and, II*b*, when one of its longer edges is against the blade of the T-square its upper edge is parallel to the front-to-back or *a* axis of the clinographic projection. A third triangle *III*, figure 23, is for the hexagonal system, and is so made that when its longer edge is against the blade of the T-square its upper left-hand edge is parallel to the $a_1$, $-a_1$ axis, and its upper right-hand edge parallel to the $a_2$, $-a_2$ axis of the clinographic projection; compare figure 10. Thus with T-square and triangles, the axial directions, the essential ones in the construction of a crystal figure, may be had almost instantly, excepting, of course, some of the directions of the monoclinic and triclinic systems.

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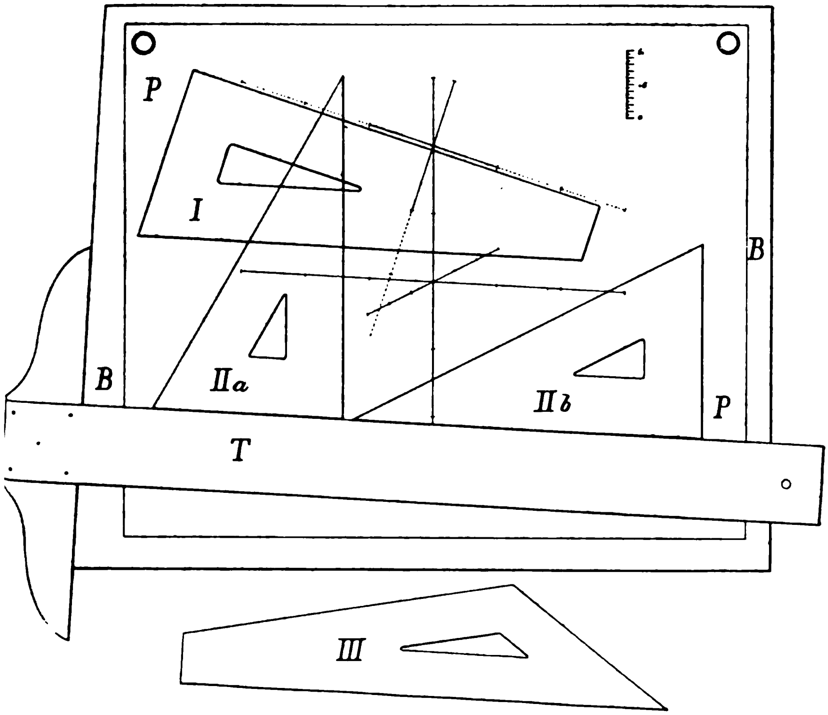

*Uses of the Linear or Quendstedt Projection.*—In drawing crystals various methods may be employed for finding the direction of an edge made by the meeting of any two faces, but the principle depends generally upon locating two points, common to both faces, where they intersect certain axial planes. A line through the points thus found gives the direction of the edge. In general it will be found best to adopt some system for determining the direction of crystal edges, and to adhere to it rather strictly, and the writer has found the method based upon the linear or Quenstedt projection most useful. The projection is too well known to crystallographers to need discussion; as far as it relates to crystal drawing, however, it will be treated briefly in order to add to the completeness of the present article.

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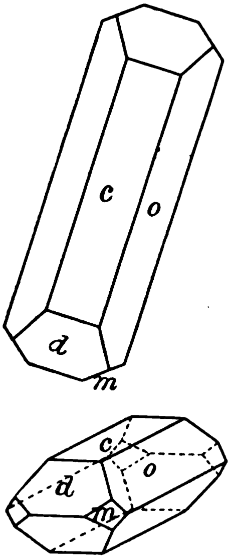

The principle upon which the projection is based is very simple: *Every face of a crystal (shifted if necessary, but without change of direction) is made to intersect the vertical axis at UNITY, and then its intersection with the horizontal plane, or the plane of the a and b axis is indicated by a line.* When it is desired to find the direction of an edge made by the meeting of any two faces, the lines representing the linear projection of the faces are first drawn, and the point where they intersect is noted. Thus a point common to both faces is determined, which is located in the plane of the $a$ and $b$ axes. A second point common to the two faces is *unity* on the vertical axis, and a line from this point to where the lines of the linear projection intersect gives the desired direction.

A simple illustration, chosen from the orthorhombic system, will serve to show how the linear projection may be employed in drawing. The example is a combination of barite, such as is shown in figure 24. The axial ratio of barite is as follows:

$$a:b:c = 0{\cdot}8152:1:1{\cdot}3136$$

The forms shown in the figure and the symbols are, base $c$ (001), prism $m$ (110), brachydome $o$ (011) and macrodome $d$ (102).

Figure 25 represents the details of construction of the orthographic and clinographic projections shown in figure 24. On the orthographic axes the axial lengths $a$ and $b$ are located, the vertical axis $c$ being foreshortened to a point at the center. On the clinographic axes, centered at $O$, the ends of the axes $a$ and $b$ are located by dropping perpendiculars from corresponding points above, and the length of the vertical axis 1·316 is laid off above and below *O* by means of the scale of decimal parts, at points marked *1* and *−1* in the figure. The lines of the linear projection needed for the two sets of axes are as follows: For the brachydome *o*, 011, the lines *xz* and *x′z′*, through *b* parallel to the *a* axis: For the macrodome *d*, 102 (2*a* : ∞*b* : *c*), the lines *xy* and *x′y′*, through 2*a* parallel to the *b* axis: The prism *m* (110) is parallel to the vertical axis,

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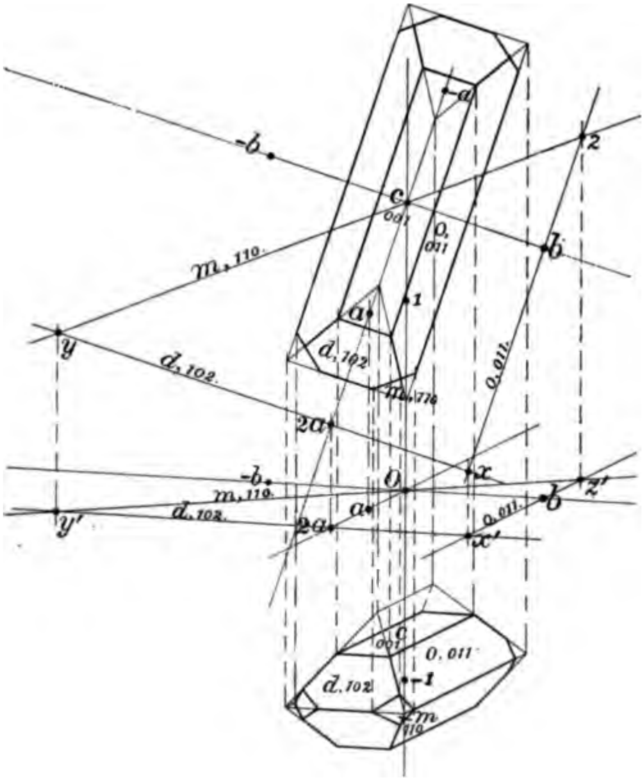

hence in order that such a plane shall satisfy the conditions of the linear projection and pass through *unity on the vertical axis*, it must be considered as shifted (without change of direction) until it passes through the center: Its linear projection therefore is represented by the lines *yz* and *y′z′*, parallel to the directions *a* to *b* on the two sets of axes. Since a linear projection is made on the plane of the *a* and *b* axes, the intersection of any face with the base (001) has the same direction as the line representing its linear projection. It is well to note that the intersections *x*, *y* and *z* and *x'*, *y'* and *z'* are in vertical alignment with one another.

Concerning the drawing of figure 25, it is a simple matter to proportion the general outline of the barite crystal in orthographic projection. The direction of the edge between *d*, 102, and *o*, 011, is determined by finding the point *x*, where the lines of the linear projection of *d* and *o* intersect, and drawing the edge parallel to the direction from *x* to the center *c*. The intersection of the prism *m*, 110, with *d* and *o* is a straight line, parallel to the direction *a* to *b* or *y* to *z*. To construct the clinographic figure, at some convenient point beneath the axes the horizontal middle edges of the crystal may be drawn parallel to the *a* and *b* axes, their lengths and intersections being determined by carrying down perpendiculars from the orthographic projection above. The intersection between *d*, 102, and *o*, 011, is determined by finding the point *x'* of the linear projection and drawing the edge parallel to the direction from *x'* to 1 (*unity*) on the vertical axis, while the corresponding direction below is parallel to the direction *x'* to *−1*. The size of the prism *m*, 110, and its intersections with *d* and *o* may all be determined by carrying down perpendiculars from the orthographic projection above, but it is well to control the directions by means of the linear projection: The edges between *m*, 110, and *d*, 102; and *m*, 110, and *o*, 011, are parallel respectively to the directions *y'* to *1* and *z'* to *1*. Having completed a figure, a copy free from construction lines may be had by placing the drawing over a clean sheet of paper and puncturing the intersections of all edges with a needle-point: An accurate tracing may then be made on the lower paper.

Should it happen that the linear projection made on the plane of the *a* and *b* axes gives intersections far removed from the center of the figure, a linear projection may be made on the clinographic axes either on the plane of the *a* and *c* or *b* and *c* axes, supposing that the faces pass, respectively, through *unity* on the *b* or the *a* axes.

*Importance of an Orthographic in connection with a Clinographic Projection.*—There is no question in the writer's mind that many students, on commencing the study of crystallography, fail to derive the benefit they should from the figures given in text-books. Generally clinographic projections are given almost exclusively, with perhaps occasional basal or orthographic projections, and beginners find it hard to reconcile many of the figures with the appearance of the models and crystals which they are intended to represent. For example, given only the clinographic projection of barite, figure 24, it takes considerable training and knowledge of the projection employed to gain from the figure a correct idea of the proportions of the crystal which it actually represents. This may be shown by comparing figures 24 and 26, which represent the same crystal, drawn one with the *a*, the other with the *b* axis to the front. It is seen from figure 26 that the crystal is far longer in the direction of the *a* axis than one would imagine from inspection of only the clinographic projection of figure 24. The front or *a* axis is much foreshortened in clinographic projection, consequently by the use of only this one kind of projection there is a two-fold tendency to err; on the one hand, in drawing, one is inclined to represent those edges running parallel to the *a* axis by lines which are considerably too long, while, on the other hand, in studying figures there is a tendency to regard them as representing crystals which are too much compressed in the direction of the *a* axis. By using orthographic in connection with clinographic projections these tendencies are overcome. Having in mind the proportions of a certain crystal, or having at hand a model, it is easy to construct an orthographic projection in which the *a* and *b* axes are represented with their true proportions; then the construction of a clinographic projection of correct proportions follows as a comparatively simple matter. Without an orthographic projection it would have been a difficult task to have constructed the clinographic projection of figure 26 with the proportions of the *a* and *b* axes the same as in figure 24, while with the orthographic projection orientated as in figure 26 it was an easy matter. Then again, given a model for study, say of barite corresponding to figure 24, a student holding the model properly orientated, over or near to the orthographic projection, and looking down on it from above, sees at once the relations between the model and the figure: Prismatic angles have their true value in the drawing, and the directions and relative lengths of all of the edges appear to be the same as on the model. From an orthographic projection alone, however, one can gain no conception of the length of a crystal in the direction of the vertical axis, nor of the steepness of its terminal faces: A combination of two projections is needed, and from two figures a proper conception of the development

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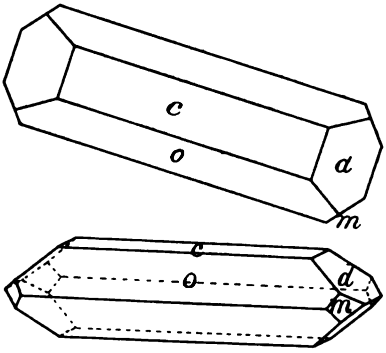
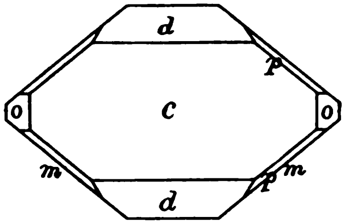


of a crystal may be had. Without question, in many and perhaps the majority of cases, figures in orthographic projection would be far more helpful to beginners, especially if studied in connection with models, than the ones so commonly used which are in clinographic projection alone. An architect in working out the details for any structure would never think of submitting to a builder a plan alone, or only an elevation: Two kinds of figures are considered as necessary, plans and elevations, and in like manner students of crystallography need figures drawn in two projections in order to derive the full benefit from them.

27



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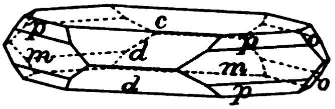
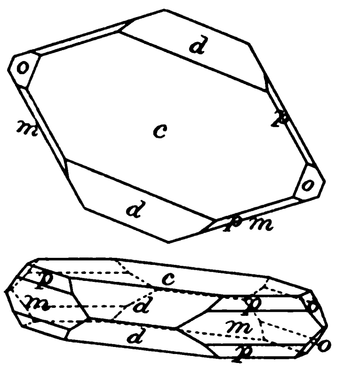


*Position of Figures.*—If orthographic and clinographic projections are to be used together there is some choice as to the position in which the figures should be placed. Taking barite as an example: If an orthographic projection alone were employed there is no question but that the drawing should be orientated as in figure 27, with the direction of the *a* and *b* axes parallel respectively to the vertical and horizontal edges of the page. Provided two projections are used, however, if the clinographic, figure 28, is placed to one side of the orthographic, or directly below it, the apparent connection between the two figures is not at all evident: To place them thus is in violation of the principles of mechanical drawing and projection, and it is hard to realize that figures 27 and 28 are representations of the same crystal. Placed as in figure 29, however, it takes but little study to understand how the two projections are related. It is true that it may at first seem strange to see the orthographic projections skewed around at

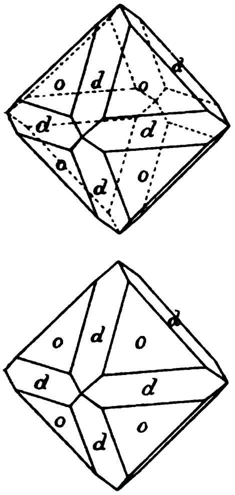
29



an angle of 18° 26′, but this is a condition to which one would soon become accustomed. If orthographic and clinographic projections are to be used together for purposes of illustration, it is believed that the orthographic projections should be left in the position in which they were drawn, and printed as in figure 29, although this is a matter which need not be insisted upon.

*Stereoscopic Effect.*—It has frequently been observed that the figures in text-books do not convey to many students the impression of solidity, and this is a defect which probably has been generally recognized. Some have sought to overcome the difficulty by making use of two projections drawn at slightly different angles, as a crystal would appear if seen from the positions of the right and left eyes, and then viewing the two pictures with a stereoscope. The effects produced are most satisfactory, but for purposes of text-book illustration and for class-room work the method is scarcely practical. If a clinographic projection is well drawn, with the front edges represented by full lines and the back edges by somewhat lighter, dashed lines, a very satisfactory and at times quite remarkable stereoscopic effect may be had by viewing the figure through a tube. The practice is one commonly employed by artists in studying effects. The tube may be a roll of light or dark paper, either cylindrical or conical, quite variable in size (6$^{cm}$ long by 1$^{cm}$ diameter gives good results), while the most convenient thing to use is one's hand, doubled up so as

30



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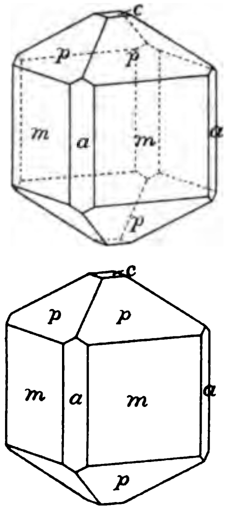

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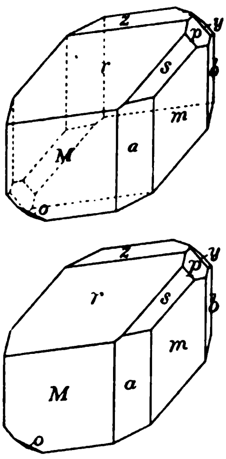
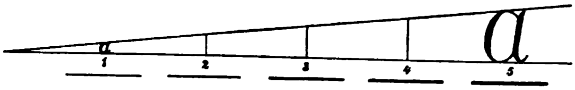


to form a sort of tube. Stereoscopic effects are more pronounced with some figures than with others, but they would seem to depend to a large extent upon the proper proportioning of the heavier front and lighter (dashed) back lines. It is believed that the reason for the stereoscopic effect is not far to seek;—it seems to be wholly an optical illusion.—By looking through a tube the attention is concentrated on a single figure, and the heavy lines produce the effect of being near, the fainter, dashed lines of being farther away; hence the conception of solidity. In order that the stereoscopic effect may be observed by the reader, illustrations of three crystals are given for comparison, drawn with and without dashed back lines; Figure 30 is a combination of dodecahedron, *d*, and octahedron, *o*, magnetite; figure 31 is a combination of prisms of the first and second order, *m* and *a*, terminated by pyramid and base, vesuvianite; and figure 32 is a combination of triclinic forms observed on axinite. Except for stereoscopic effect it may be questioned whether dashed back lines are not at times as much of a hindrance as a help in the understanding of crystal figures, because of the complexities which they introduce. As a rule they certainly add to the effectiveness of a figure, but not always; for example, in figure 18, page 50, it seemed far better to do without them.

33

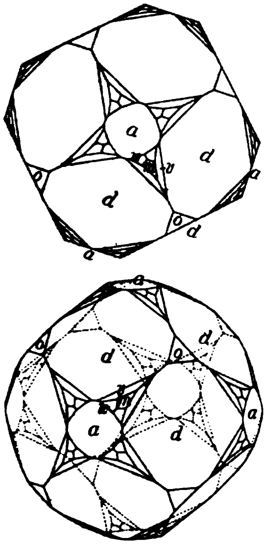


*Size of Original Drawings; Lettering.*—Generally speaking, the size of an original drawing should depend to a large extent upon the complexity of the figure. It may be recommended to draw simple figures three or four times as large as needed for illustration, while with a complex subject like figure 34 it is almost impossible to make a drawing with accuracy except on a scale seven or eight times the size of the illustration. Figure 34 represents a crystal with 240 edges; hence it is evident that it is necessary to make the original drawing on a large scale in order to preserve with accuracy the directions of the many short lines.

If figures are to be reduced by the photo-engraving process, they must be drawn in ink and lettered to suit the reduction. Figure 33 gives the approximate width of line and size of letter to be used with various degrees of reduction indicated by the numbers. Almost any one can succeed fairly well in forming letters who will take pains and make use of good models.

*Uniformity of Lettering.*—A gain has been made in recent years in adopting some uniformity in lettering, as must be appreciated by all who are accustomed to use Dana's System of Mineralogy. The scheme there adopted is in general to indicate the three pinacoids, 100, 010 and 001, by *a*, *b* and *c*, respectively, and the prism 110 by *m*. In the hexagonal and rhombohedral systems the prisms of the first and second orders are designated by *m* and *a*, respectively, in conformity with the usages of the tetragonal system, and the unit rhombohedron is designated by *r*. In the isometric system the cube, octahedron and dodecahedron are lettered *a*, *o* and *d*, respectively. The writer recommends going still one step further and designating the form 111 (isometric system excepted) always by *p*, but to carry the scheme beyond this point would be cumbersome and scarcely practicable. In using Dana's Mineralogy, or reading any article in which the scheme as outlined above is followed, a glance at the figures will generally serve to indicate the character of the forms, for however complicated a crystal may be, it is almost certain that some of the above mentioned forms will be present. It is hoped that the scheme will be more generally adopted than it is at present.

34



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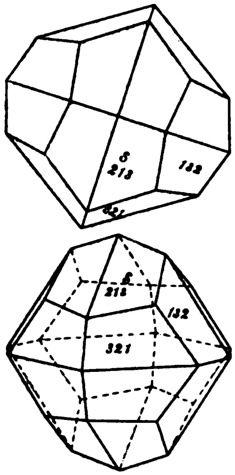

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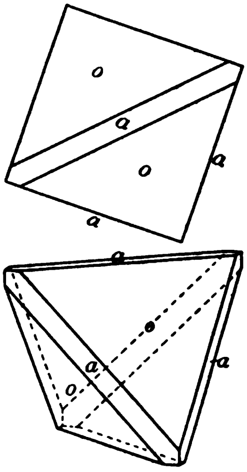
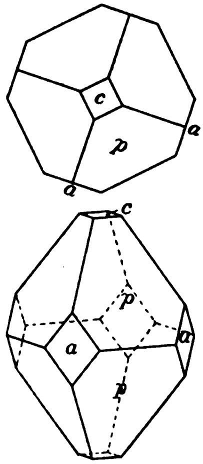


*Examples.*—In conclusion some figures will be given illustrating numerous advantages derived from drawing crystals in both orthographic and clinographic projection.

For the normal group of the isometric system, the forms observed on a specimen of magnetite in the Brush Collection, from Achmatowsk, Ural Mts., figure 34, has been chosen. The figure was drawn by Mr. R. G. Van Name when a student in the writer's laboratory. The combination is unusually complex, trapezohedron *m* (311) and two hexoctahedrons, *v* (531) and *w* (21 . 7 . 5), besides the simple forms *a*, *o* and *d*. A similar combination, but with somewhat different development of the forms, is described by Kokscharow.* In the construction of the complex clinographic figure, the orthographic projection proved to be a great help.

37



Both in drawing and in the study of forms of lower symmetry, orthographic projections are very helpful. Figure 35 represents the diploid *s*, (321), and figure 36 a combination of cube *a* and tetrahedron *o*. It is the writer's experience that the average student has great difficulty in gaining an idea of tetrahedral forms from figures in clinographic projection, yet a combination of cube and tetrahedron if orientated and looked at from above, in the direction of the vertical axis, will appear exactly like the orthographic projection of figure 36, hence the value of the figure.

Figure 37 represents a simple combination of the tetragonal system observed on apophyllite; prism of the second order *a*, base *c*, and pyramid of the first order *p* (111). The clinographic projection alone gives a very satisfactory idea of the general proportion of the crystal, but the imagination must be drawn on to grasp the idea that the pyramid is tetragonal, a property which is brought out by a glance at the accompanying orthographic projection.

Figure 38 is a combination belonging to the tri-pyramidal group of the tetragonal system, observed on scapolite from Templeton, Canada. The forms are two prisms *a* and *m*, terminated by pyramids of the first order *p* (111) and *w* (331), of the second order *e* (101) and of the third order *z* (311). From the standpoint of a student desiring to understand the relations of the three kinds of pyramids of this group, it is believed that the orthographic is the most helpful of the two projections, although the clinographic is needed to give an idea of the general proportions of the crystal.

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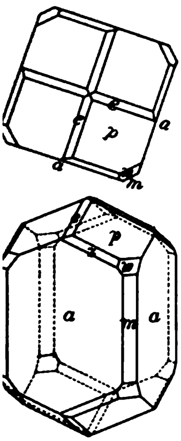
* Mineralogie Russlands, vol. iii, p. 47.

In the combination observed on beryl, *c* (0001), *m* (10$\bar{1}$0),
(10$\bar{1}$1) and *s* (11$\bar{2}$1), figure 39, it takes considerable imagina-
ion to grasp the idea of the hexagonal shape and distribution
f the pyramidal forms from the clinographic projection alone,
elations which are at once brought out with distinctness by
ieans of the accompanying orthographic projection. In the
hombohedral group of the hexagonal system clinographic
rojections alone are at times quite inadequate for represent-
ig the shapes of crystals. For example, given the clinographic

38



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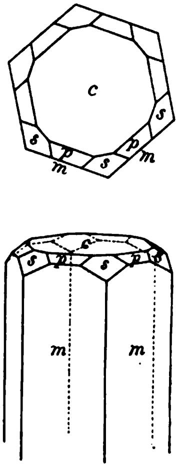

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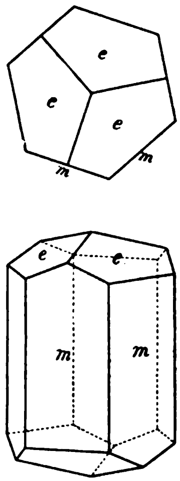
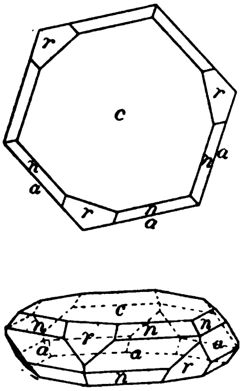


rojection alone, figure 40, it may well be imagined that be-
inners have difficulty in understanding the simple type of
ilcite crystal represented, prism *m*, terminated by the flat
egative rhombohedron *e* (01$\bar{1}$2), but with the accompanying
thographic projection, the hexagonal nature of the prism
id the distribution of the terminal faces about the vertical
cis with trigonal symmetry is evident. The two projections,
gure 41, supplement one another in giving an idea of the pro-
ortions and arrangement of the faces observed on a crystal of
orundum from Cowee Creek, Macon Co., N. C. Figure 42
presents a crystal of hematite from Fowler, N. Y., showing
ie combination of the base *c* and a very flat rhombohedron *x*
·1·$\bar{1}$·12). In this case the clinographic projection alone is quite
adequate, for although the figure is a correct representation
so far as the projection is concerned, it is next to impossible
gain from it a correct conception of the shape and propor-
ons of the crystal which it is intended to represent. The

orthographic projection above, accompanied by the statement that the rhombohedron is very flat, $c \wedge x = 7^\circ\ 29'$, enables one to gain an idea of the shape of the crystal, while a second orthographic projection which represents the crystal when viewed edgewise, that is so that the base is foreshortened to a line, has been introduced to indicate how very thin the crystal really is.

For the orthorhombic system, illustrations have already been given of the use of orthographic projections both in drawing

41



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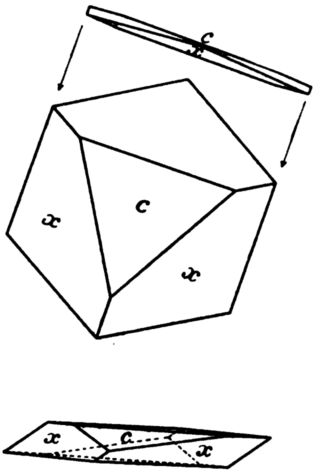

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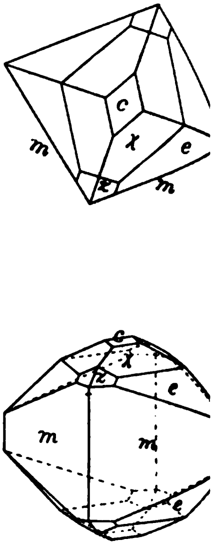
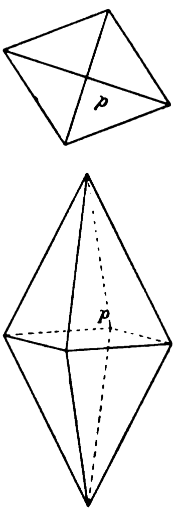


and in the understanding of the forms of barite crystals. Figure 43 is offered as an additional illustration: It represents a combination observed on brookite from Magnet Cove, Arkansas. From the clinographic projection alone it is very difficult to gain an appreciation of the proportions of the crystal; while the orthographic projection is excellent for showing the distribution of the terminal faces and zonal relations. Figures 44 and 45 represent pyramids of sulphur and octahedrite, respectively. Considering the clinographic projections alone, it takes careful inspection to discover any difference between the two figures, while the accompanying orthographic projections indicate at a glance that the pyramid is orthorhombic in the one case and tetragonal in the other.

In the monoclinic system, the clinographic projections alone, figures 46, 47 and 48, need to be supplemented by the accompanying orthographic projections in order that the real shapes of the crystals may be fully appreciated. Taking another example; it has always seemed to the writer that the clinographic projection of epidote, figure 49, was poorly adapted for showing the form of so simple a crystal. It represents a combination lengthened in the direction of the *b* axis and terminated by two faces *n* ($\bar{1}11$), one of which, however, in the position adopted, happens to be foreshortened to a line. The accompanying orthographic projection, especially if studied in connection with a model, helps to give an understanding of the shape. A clinographic projection better adapted for giving an idea of the development of the crystal is shown in figure 50.

44



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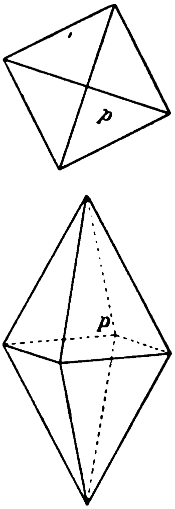

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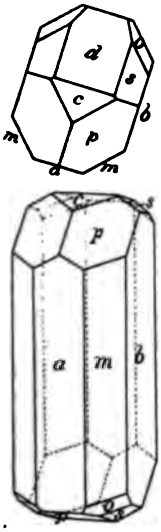
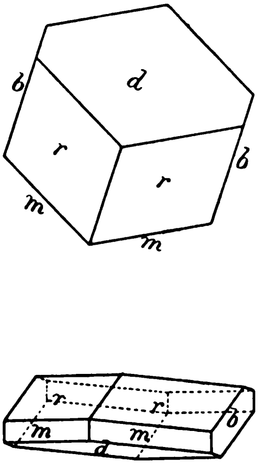


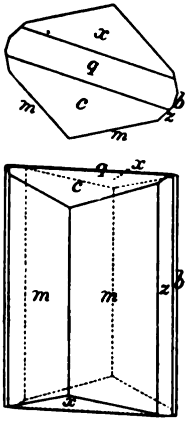
Pyroxene.

47



Tremolite.

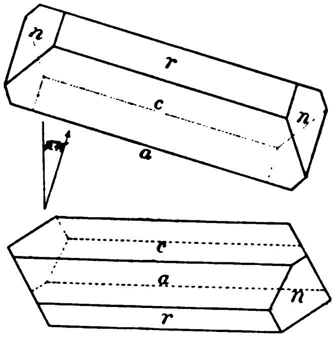
48



Adular.

In this case the revolution about the vertical axis is 28° 26′ instead of 18° 26′, as in the previous illustrations, and both terminal faces are thus shown in the lower figure. By means of the axial protractor, page 44, it is an easy matter to plot the axes in the position chosen.

49



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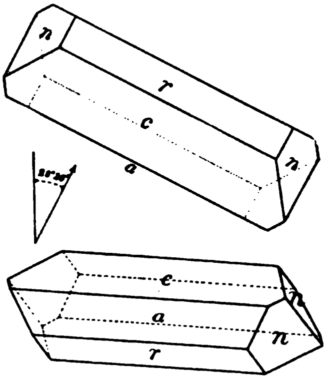

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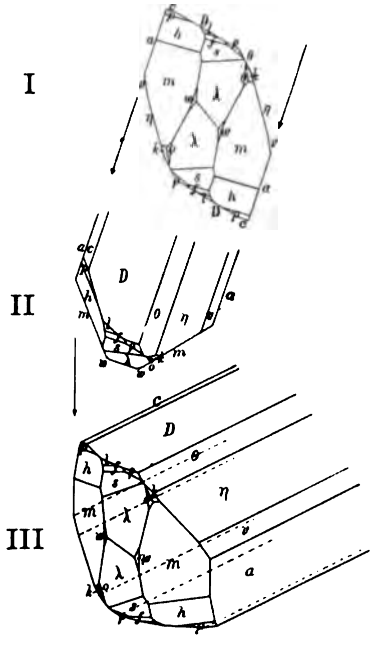
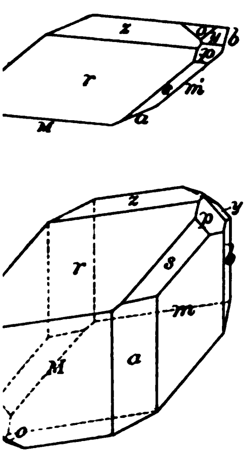


Owing to foreshortening, without the use of an orthographic projection it often becomes a very difficult matter to construct a figure in clinographic projection in which the relative proportions of the several faces of a crystal are preserved with accuracy. A case illustrating this, encountered in the study of some very beautiful and complex crystals of azurite from Broken Hill mines, New South Wales, figure 51, may be cited. The drawings were made by Mr. R. G. Van Name when a student in the writer's laboratory. The crystals, lengthened like epidote in the direction of the *b* axis, showed only one termination, and the clinographic projection III represents the crystal turned so that the *b* axis runs from front to back. The list of forms is not given here because, if needed, it may be found in an earlier publication.* Endeavoring to preserve the true proportions of the faces, it proved to be a difficult matter to construct the orthographic projection II, as seen in the direction of the vertical axis. An end view of the crystal, an orthographic projection as seen in the direction of the *b* axis I, was therefore first drawn, a comparatively easy task, and tilting it at an angle of 18° 26′, as shown in the figure, the

52



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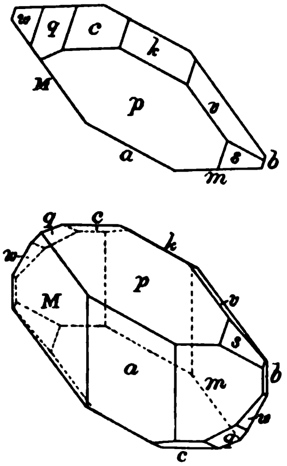

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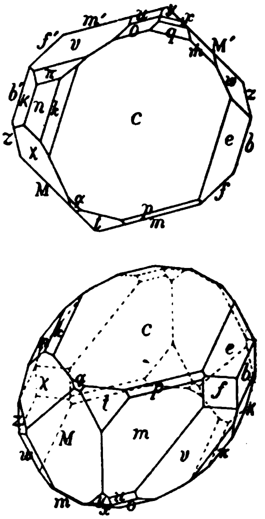

orthographic projection II was readily made by projecting as indicated by the arrows, and, finally, the clinographic projection III, in exactly the desired proportions was made. In studying the forms of a complex crystal, such as represented by figure 51, the orthographic projection I (end view) is doubtless more satisfactory than either of the other projections.

For the triclinic system three illustrations are offered. The clinographic projection of axinite, figure 52, is very satisfactory, but its proportions are made more real by the accompanying orthographic projection. In the examples chalcanthite and anorthite, figures 53 and 54, the clinographic projections taken alone are inadequate because of the foreshortening of several of the prominent faces, but supplemented by the accompanying orthographic projections the combinations are readily understood. The complicated figure of anorthite was drawn by Mr. J. C. Blake of the writer's laboratory.

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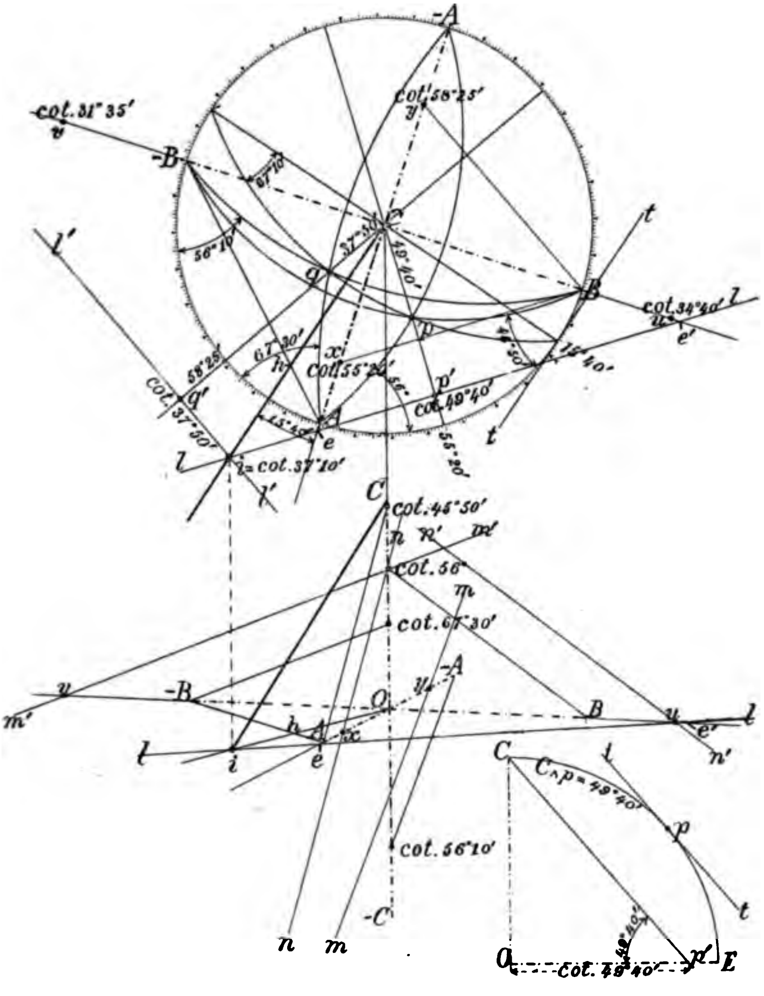
* This Journal (4), xiv, p. 278, 1902.

*Conclusion.*—It is not the object of the present communication to make the subject of crystal drawing easy. The drawing of a complex combination requires patience, skill, and above all a knowledge of the principles of crystallography and mechanical drawing. For some persons the subject is a very easy one, while others acquire it only with difficulty, differences depending upon personal peculiarities. That correct ideas of the shapes of crystals should be obtained from figures is evident, and those who are familiar with crystallography, especially if they are not called upon to teach it, have difficulty perhaps in appreciating how hard it is for some persons to see the relations between a figure and the crystal which it represents. The clinographic projection is undoubtedly as good a one as can be found for representing the shapes of crystals, but, as has been pointed out, in many cases a figure thus drawn should be supplemented by one in orthographic projection. Orthographic projections are so simple that they may be made easily, even sketched free hand with some approximation to accuracy, and it is especially desired to emphasize their value as a help both in drawing and in the understanding of crystal figures. In the majority of cases two figures, one in orthographic and the other in clinographic projection, may be made in less time than a single figure in clinographic projection. The engraved axes, axial protractor and special triangles, having been in use for more than four years in the writer's laboratory, have proved their efficiency: by means of them increased accuracy in drawing is attained, time is saved, and, what is of no little importance, strain on the eyes is materially lessened.

*Drawing from the Stereographic Projection.*—A stereographic projection of the faces of a crystal, or, for that matter, of any geometrical figure with plane surfaces, furnishes all the data needed for constructing figures in both orthographic and clinographic projections. In the methods to be described use will be made of three lines or axes; one a vertical, corresponding to the north and south axis of a sphere, the others at right angles to one another in the plane of the equator. In the upper part of figure 55 the two diameters of the graduated circle, $A$, $-A$ and $B$, $-B$, represent the front-to-back and right-to-left axes in the plane of the equator, the vertical axis, $C$, $-C$, being foreshortened to a dot at the center. The axes have been turned as it were through an angle of 18° 26′ in order to make $A$, $-A$ and $B$, $-B$ correspond with the directions of the axes for orthographic projection of figure 1. It is supposed that in figure 55 $p$ is the pole of some crystal face: From the graduated circle it is seen that $p$ is on the meridian

55° 20′, measured from *B*, and the distance from *C* is easily determined as 49° 40′ by means of a stereographic scale.* If

55



we imagine a pole corresponding to *p* located on a spherical surface, a plane surface tangent to the sphere at $p$ would be parallel to the crystal face under consideration, and, if extended, it would intersect the plane of the equator on a line at right angles to a radius drawn through the intersection of the meridian of $p$ and the equator. In the lower right-hand corner of figure 55 the arc $CE$ is supposed to represent a portion of the meridian through $p$; $C$ is the north pole of the sphere, $OE$ the trace of the plane of the equator and $tt$ the trace of the tangent at $p$: If now the tangent plane is shifted, without change of direction, until it intersects $C$ (*unity* on the vertical axis) it will intersect the radius $OE$ in the plane of the equator at $p'$. The linear projection of $p$ is therefore found by determining the point $p'$, where a plane parallel to the tangent at $p$ and intersecting the vertical axis at $C$ cuts the radius drawn through $p$, and then drawing the line of the linear projection, $ll$, at right angles to the radius. Knowing the distance $C$ to $p$ in degrees, the point $p'$ where the line $ll$ crosses the radius through $p$ may be readily found in three ways: (1) Graphically, as shown in the lower right-hand corner of figure 55; (2) From the same figure it is evident that $Op'$ is the cotangent of the angle $Cp'O$ or of the arc $C{\wedge}p$; the value of the cotangent may be found from a table of natural tangents and cotangents and laid off on the radius through $p$ by means of a scale of decimal parts; (3) A cotangent scale may be prepared, based on the radius of the circle as *unity*, and the distance $Cp'$ laid off directly from the graduation. The latter method is probably the best, and a scale for laying off cotangents may be easily had by a simple modification of the stereographic scale, No. 3, of the engraved sheets described by the writer.* The basis of the stereographic scale is that the distance from the center to any pole, for example, $C$ to $p$, figure 55, is equal to the tangent of half the arc $C{\wedge}p$; hence in order to prepare a scale for laying off tangents and cotangents it is only necessary to take a stereographic scale and renumber it, making 20° of the one equal to 10° of the other. On applying such a scale to a radius of the graduated circle for laying off cotangents, 90° is located at the center (the cotangent of $90^\circ = 0$), and 0° falls at infinity. The reason for using a cotangent instead of a tangent scale (when the numbering would run in the opposite direction) is that cotangents are better adapted to the $\phi$ and $\rho$ angles of the two-circle goniometer. Having a second pole $q$, 37° 50′ from $C$, figure 55, its linear projection is the line $l'l'$. The two lines of the linear projection $ll$ and $l'l'$ intersect at $i$, and the direction of the edge made by the intersection of $p$ and $q$ will be parallel to the line joining $C$ and $i$.

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* For a description of the stereographic scales and protractors mentioned in this and the succeeding paragraphs, the reader is referred to the earlier publications of the writer: "The Stereographic Projection and its Possibilities from a Graphical Standpoint," this Journal (4), xi, pp. 1–24 and 115–144, 1900; and "On the Solution of Problems in Crystallography by Means of Graphical Methods, based upon Spherical and Plane Trigonometry," Ibid., xiv, pp. 249–284, 1902.

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*Loc. cit.

Still another way in which the direction *Ci* may be found is as follows: Among the stereographic protractors described by the writer there was one consisting only of great circles printed on celluloid (Protractor No. *IV*). Having *p* and *q* located, the protractor is centered over the projection and turned until *p* and *q* fall on the same great circle, and then the points where the great circle intersects the divided circle (15° 40′ from *B* in figure 55), are noted, although it is not necessary to draw the great circle as in the figure. It follows from this that *p* and *q* are in a zone with a vertical plane, the pole of which is located at 15° 40′ from *B*: The intersection of such a vertical plane with the plane of the equator would be parallel to the line *tt*, tangent at 15° 40′, or, simpler, it would be parallel to a line from the center *C* to a point on the graduated circle 15° 40′ from *A*, which is identical with the direction *Ci* found by means of the linear projections of *p* and *q*. The method of the great circle protractor has one decided advantage; it is not necessary to make any construction lines; the position of the protractor alone determines the desired direction. The line *Ci* in orthographic projection may be regarded as representing two things: (1) a radius drawn on the plane of the equator, and (2) the projection of the edge between *p* and *q*, passing through unity on the *C* axis and intersecting the plane of the equator at *i*: the point *i* is an important one to determine, and may be found by noticing the angle which the great circle through *p* and *q* makes with the diameter, 37° 10′ in figure 55, and locating *i* by means of the cotangent scale.

In order to find the intersection between two planes in clinographic projection, *p* and *q*, figure 55, proceed as follows: Through *C* and a point 18° 26′ to the right of *A* on the graduated circle, draw a line, and continue it for some distance below the circle, to represent the vertical axis. As shown in figure 23, page 53, the vertical axis is next made parallel with the edge of the special triangle II*a* resting on a T-square, then, at some convenient distance *O*, the lines *B*, −*B* and *A*, −*A* are drawn with the aid of a T-square and the special triangle II*b* to represent the right-to-left and front-to-back axes. Unit lengths on the axes are determined by projecting down from *A*, −*A* and *B*, −*B* of the orthographic axes above, and a distance equal to the radius of the graduated circle is laid off above and below *O*, at *C*, and −*C*, to represent unity on the vertical axis. If the special triangle referred to is not at hand, the clinographic *A*, −*A* and *B*, −*B* axes may be constructed readily from the details given on pages 40 and 41, in connection with figures 1 to 4. If on the orthographic axes above the linear projection of *p*, that is the line *ll*, has been drawn, its intersections with the *A* and *B* axis, *e* and *e'*, are noted and points corresponding to this are projected down on the clinographic axes beneath. The line *ll*, through *e* and *e'* on the lower axes, is the linear projection of *p*. The point *i*, the intersection of *ll* and *l'l'* of the orthographic projection above, may now be transferred to the line *ll* of the lower axes by projecting down parallel to the vertical axis: the intersection between *p* and *q* is parallel to the line from *C* to *i*. If the point *i* on the upper axes has been determined by means of the cotangent scale, without the use of the linear projection, the corresponding point *i* on the lower axes may be found as follows: On both the upper and lower axes draw lines from *A* to $-B$, and on the upper axes note the point *h* where the lines *A* to $-B$ and *Ci* cross; on the lower axes find the corresponding point *h* on the line *A* to $-B$ by projecting down from *h* above, draw a line from *O* through *h* and find *i* by projecting down from *i* above.

In following out the methods just described, two conditions may be encountered which give rise to difficulties; (1) the pole of a certain crystal face may be located within a few degrees of the center of the stereographic projection, in which case the line representing its linear projection would be so far removed from the center that it is difficult to construct it, and (2), two lines of a linear projection may happen to be so nearly parallel that their intersection falls too far from the center of the figure for convenience of drawing. Such difficulties may be overcome easily by making the linear projection either on the plane of the *A* and *C* axes, supposing the faces to pass through *unity* on *B*; or on the plane of the *B* and *C* axes, supposing that the faces intersect *unity* on *A*. To illustrate how a linear projection may be made on the plane of the *A* and *C* axes:—The pole *p*, figure 55, is on the meridian 55° 20′ from *B*, and a crystal face corresponding to *p* would intersect the plane of the equator at right angles to a radius drawn to a point on the equator 55° 20′ from *B*; such a plane if shifted so as to intersect *B* at *unity* would intersect the *A* axis at the point marked *x*, cot. 55° 20′ (best laid off with the cotangent scale), which is projected down upon the *A* axis beneath. The great circle stereographic protractor is next centered over the projection, and it is found that the great circle passing through *B* and *p* makes an angle of 45° 50′ with the equator at *B*; hence it follows that all the possible faces in the zone *Bp*, if made to intersect *A* at unity, would intersect the vertical axis at a distance equal to the cotangent of 45° 50′ measured from the center. By means of the cotangent scale the point cot. 45° 50′ is laid off from *O* on the vertical axis and the linear projection of *p* is the line *nn*, drawn through *x*, previously determined, and parallel to the direction from *A* to the point cot. 45° 50′ on the vertical axis. In the case of *q*, figure 55, being on the meridian 58° 25′ from −*B*, a little explanation is necessary: A crystal face corresponding to *q*, when shifted so as to intersect +*B*, will intersect the negative ends of the *A* and *C* axes; the former at the point marked *y*, cot. 58° 25′, which is projected down on the *A* axis beneath. The great circle through −*B* and *q* makes an angle of 56° 10′ with the equator, and the point cot. 56° 10′ is laid off in this case on the negative end of the *C* axis. The linear projection of *q* is then the line *mm*, drawn through *y* and parallel to the direction from −*A* to the point cot. 56° 10′ on the vertical axis. The lines *nn* and *mm* ntersect at some distance from the cener of the axes, but f continued it is found that a line from +*B* to their point of ntersection is parallel o the direction *Ci*. f it is desired to make he linear projection

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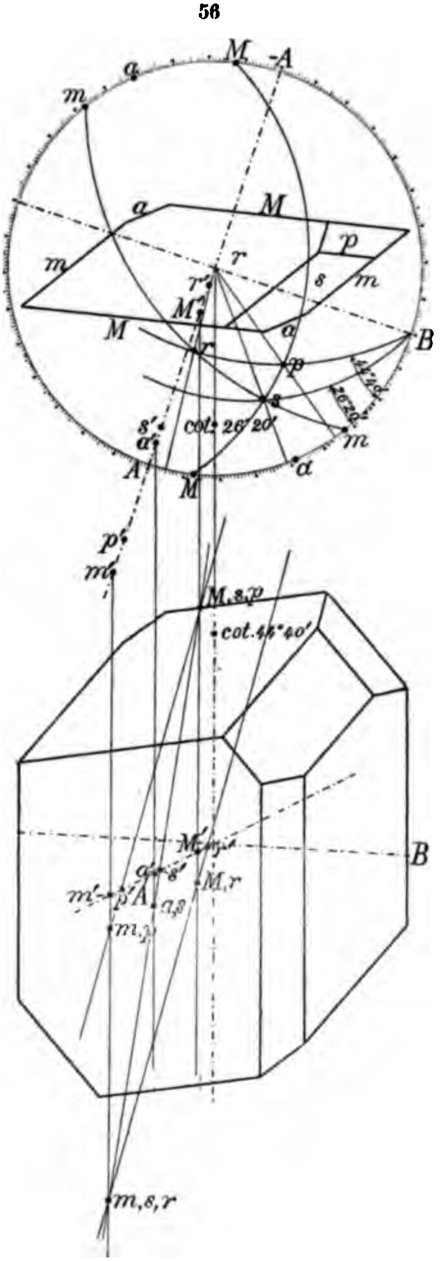

on the plane of the $B$ and $C$ axes, the data are as indicated in figure 55: The meridians of $p$ and $q$, 34° 40′ and 31° 35′, measured from $A$ (their cotangents plotted at $u$ and $v$), and the angles which the great circles through $A$ and $p$ and $A$ and $q$ make with the equator, 56° and 67° 30′, respectively. The linear projection of $p$ is the line $n'n'$, drawn through $u$ parallel to the line from $B$ to the point cot. 56° on the vertical axis; and the linear projection of $q$ is the line $m'm'$, drawn through $v$, parallel to the line from $-B$ to the point cot. 67° 30′ on the vertical axis. A line drawn from $A$ to the point of intersection of $n'n'$ and $m'm'$ is the desired direction, and is parallel to the line $Ci$.

As an illustration of the application of the methods just described, the details of a drawing of a crystal of axinite may be cited. The forms present are shown in the stereographic projection, figure 56: $m$ (110), $a$ (100), $M$ $(1\bar{1}0)$, $p$ (111), $r$ $(1\bar{1}1)$ and $s$ (201). It was found that on making the linear projection on the plane of the $A$ and $B$ axes, several of the lines were so nearly parallel that it was difficult to determine some of the intersections. It was decided, therefore, to make the linear projection on the plane of the $A$ and $C$ axes as shown in the figure, the data needed being derived from the stereographic projection, as follows: Meridians of the poles, measured from $B$: $m$ 32° 47′; $p$ 35° 50′: $a$ 48° 21′; $s$ 51°; $M$ 77° 16′ and $r$ 85°; also the angles made by the great circles $Bpr$ and $Bs$ with the equator, 44° 40′ and 26° 20′, respectively. The cotangents of the meridians of the several poles are laid off on the orthographic $A$ axis at $m'$, $p'$, $a'$, $s'$, $M'$ and $r'$, and projected down on the clinographic $A$ axis. The linear projections of the faces of the prismatic zone are vertical lines through $m'$, $a'$ and $M'$; those of $p$ and $r$ are lines through $p'$ and $r'$, parallel to the direction from $A$ to the point on the vertical axis marked cot. 44° 40′; and that of $s$ the line through $s'$, parallel to the direction from $A$ to the point on the vertical axis marked cot. 26° 20′. All of the intersections of the figure in clinographic projection are parallel to lines drawn from $B$ to points of intersection on the linear projection, indicated by the lettering. Thus the orthographic and clinographic figures of axinite were made wholly without reference to the lengths and inclinations of the triclinic axes and the symbols of the faces.

Figure 57 represents a cut stone (brilliant) as seen from above, and figure 58 as seen from below in orthographic projection, while figure 59 is a clinographic projection of the same. These drawings were made from two-circle goniometer measurements plotted in the stereographic projection. The object measured was a glass model of the Regent or Pitt diamond.

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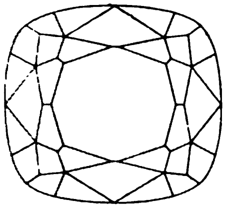

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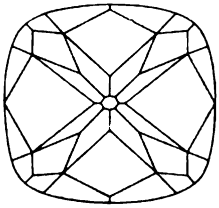

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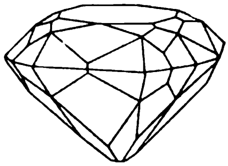

It is scarcely necessary to state that drawings may be made from gnomonic as well as from stereographic projections, with but slight modifications of the methods just described.

It is the writer's belief that the average student will find it easier to draw crystals from axes and the symbols of crystal faces, as set forth in the earlier part of this paper, than from the stereographic projection. Cases may arise, however, in which the latter methods may be found useful, as, for example, in finding the intersections between faces of twin crystals, or in representing some odd shapes which can not be referred to the axes of the crystal systems.

Mineralogical Laboratory of the
Sheffield Scientific School of Yale University,
New Haven, Conn., November, 1904.

NOTE.—If any desire to make use of the Engraved Axes, page 43, the Protractor for plotting Crystallographic Axes, page 44, or the Special Triangles, page 53, the writer will be glad to answer any communications and see that the necessary articles are supplied from his laboratory.

## Art. VI.—*Anemiopsis Californica* (Nutt.) H. et A. An anatomical study; by Theo. Holm. (With six figures in the text drawn by the author.)

With Bentham and Hooker *Anemiopsis* H. et A. and *Gyrotheca* Dcsne. are included in *Houttuynia* Thunbg., but they all have been kept separate by Eichler* on account of their floral structures. *Houttuynia* is described as possessing only three stamens opposite the three carpels, while in *Anemiopsis* and *Gyrotheca* the flower has six stamens and three carpels in the former, but four in the latter; the ovary is, moreover, perfectly inferior in *Gyrotheca*. The arrangement of the stamens in *Anemiopsis* is somewhat peculiar, as already described by Payer, there being two in front and two behind the ovary, with one on each side of this; this position of the stamens was, also, observed by the writer in the several inflorescences examined. Furthermore, DeCandolle† has treated our genus as distinct from the others.

*Anemiopsis Californica* does not seem to be very well known anatomically, and since the writer has lately received some fresh and carefully collected specimens from California through our friend Mr. Thos. H. Kearney, we have examined the plant and offer now the following notes as a small contribution to the knowledge of this peculiar genus.

The thick rhizome is horizontal with several strong and quite fleshy roots; its ramification is monopodial, the apical bud being purely vegetative, while the stolons and flower-bearing stems are all lateral, proceeding from the axils of the leaves, which form an open rosette. While, as already pointed out by Eichler (l. c.), the flowers are destitute of prophylla, such occur at the very base of both the stolons and flower-bearing stems, thus representing clado-prophylla.‡ These leaves are two in number and situated to the right and left of the stems; they are membranaceous, scale-like and prominently carinate, but simply one-nerved. The flower-bearing stems are often branched, there being one terminal and two or three lateral inflorescences preceded by one or two green leaves. The stolons show the same structure, but with vegetative shoots instead of inflorescences.

Considered from an anatomical viewpoint the *Piperaceæ*§ have always attracted a good deal of attention, and they figure prominently in works upon general anatomy. Not less than four types of stem-structure are described by Dr. Solereder (l. c.), and characteristic of the tribe *Saurureæ*, to which our genus belongs, is one normal ring of collateral mestome-bundles. In regard to the leaf-structure the stomata are said to be confined to the lower surface; in *Anemiopsis*, however, we observed these to be present also on the upper, and even more numerous. Most peculiar is the development of a hypoderm, so very prominent in *Peperomia*, besides the hydathodes. Secreting cells abound in the leaves and stems of both *Pipereæ* and *Saurureæ*, while secreting ducts are only known from some species of *Piper*. Very little seems, however, to be known about *Anemiopsis*, thus we take the opportunity to describe herewith the structure of the various organs in detail.

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* Blüthendiagramme, vol. ii, 1878, p. 6.

† Prodromus, vol. xvi. 1869, p. 237.

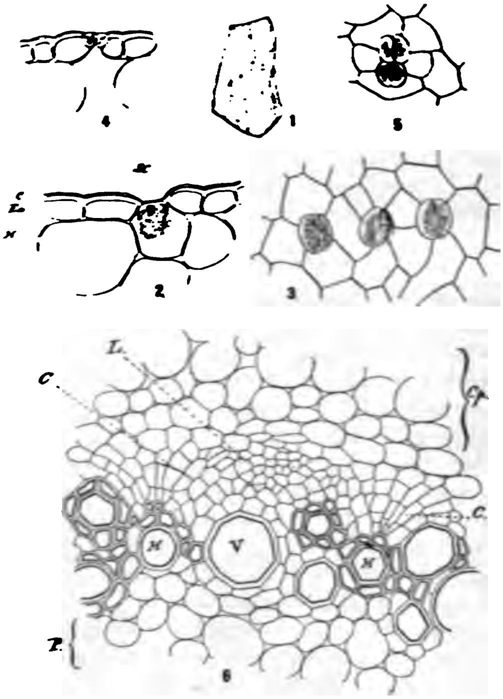
‡ Compare Casimir DeCandolle: Mémoire sur la famille des Pipéracées. (Mém. Soc. phys. Genève, vol. xviii, 1865, p. 234.)

§ The anatomy of the order has been described in Dr. H. Solereder's work: Systematische Anatomie der Dicotyledonen. Stuttgart, 1899, p. 775.

### *The leaf-blade.*

The cuticle of both surfaces is quite thick and prominently wrinkled, which is especially distinct when we examine the epidermis from above (fig. 1). Epidermis consists of relatively small cells with the outer wall moderately thickened except in the secreting cells (*SC* in fig. 2). For, as may be seen from this figure, secreting cells occur, also, in the epidermis; they are thin-walled throughout, much larger than the ordinary epidermis-cells and sunk below the level of these, thus forming round depressions in the leaf-surface. Long hairs abound on the lower surface and consist of from eight to twelve cells in one row with the cuticle thin and smooth. As stated above, we observed stomata on both surfaces, and they appeared even to be most numerous on the upper; they have no specialized subsidiary cells, but are surrounded by a somewhat indefinite number of ordinary epidermis cells, from four to six, as may be seen from our fig. 3; viewed in transverse sections, the stomata are level with epidermis (fig. 4). A hypoderm of one layer of cells (*H* in fig. 2) is developed on both faces of the blade, but of different structure; the cells are very large and cone-shaped on the upper face with the point towards the palisade-tissue; on the lower face the hypodermal cells are relatively smaller and of a roundish outline (fig. 2).

The leaf is dorsiventral and possesses a distinct palisade-tissue of several layers on the upper face, interrupted here and there by secreting cells; the palisades are rich in chlorophyll and surround the conical, hypodermal cells, but without reaching the epidermis. A pneumatic tissue of irregular, oblong cells, with wide intercellular spaces, occupies the dorsal part of the blade. The mestome-bundles, except the mediane, are small and completely imbedded in the mesophyll; they are surrounded by a colorless parenchyma-sheath. The midrib is quite broad and projects on the lower surface, where it borders on a large mass of thin-walled, colorless parenchyma. It is composed of seven separate mestome-bundles, each with a parenchyma-sheath and having a support of several layers of stereomatic tissue, especially on the leptome-side.



*Anemiopsis Californica.*

FIG. 1.—A cell of epidermis from the leaf, showing the wrinkled cuticle, seen from above.

FIG. 2.—Transverse section of the leaf; $C$ = cuticle; $Ep$ = epidermis; $SC$ = secreting cell of epidermis; $H$ = hypoderm.

FIG. 3.—Epidermis with stomata of the leaf, seen from above.

FIG. 4.—Transverse section of leaf, showing a stoma.

FIG. 5.—Epidermis with twin-stomata, seen from above.

FIG. 6.—Transverse section of a part of the central-cylinder of the root; $L$ = leptome, outside a secondary vessel $V$; $C$ = cambial layers; $H$ = the primordial rays of hadrome; $P$ = pith; $Cp$ = secondary cortical parenchyma.

*The petiole.*

The cuticle shows the same structure as described above; the epidermis possesses stomata, but no hairs, and is rather small-celled. A hypoderm is, also, developed here, but it is uniform and consists only of one layer of roundish cells. The cortical parenchyma, at least the peripheral strata, contains chlorophyll, and is very open from the great width of the intercellular spaces; secreting cells occur, also, here, but are not very frequent. Separating the cortex from a central group of parenchymatic tissue, a pith, is a circle of twelve collateral mestome-bundles, each with a thin-walled parenchyma-sheath, and surrounded besides by strata of stereomatic tissue. The stereome, however, is confined to the periphery of the mestome-bundles themselves, and does not connect these as a continuous ring of mechanical tissue as is the case with the stem. Characteristic of the mestome-bundles in the petiole is their elliptical outline in cross-section with the leptome, forming a narrow, linear group in contrast to the broad group of hadrome with numerous, narrow vessels.

### *The prophylla.*

As already mentioned, the stolons and flower-bearing stems are axillary; they bear at their base two scale-like, membranaceous fore-leaves, the structure of which is as follows: The cuticle is very distinctly wrinkled on the outer, the dorsal face, but smooth on the inner, the ventral. Epidermis is thin-walled and consists of relatively small cells throughout with neither trichomes or stomata; the outermost portion of the margins is merely composed of epidermis in two layers corresponding to the dorsal and the ventral. The mesophyll is very poorly represented except in the sharp keel; it is quite open and does not contain chlorophyll, neither is it differentiated as a palisade or pneumatic tissue, but constitutes a homogeneous tissue of roundish, thin-walled cells. There is only one mestome-bundle, which is located in the keel; it has a support of two or three layers of slightly thickened stereome and contains mostly leptome.

### *The involucre.*

The involucral leaves at the base of the inflorescence are very conspicuous, being large and white; they are prominently papillose on the ventral face, each epidermal cell being extended into an obtuse papilla, while the dorsal face is perfectly smooth. Stomata and secreting cells occur in the dorsal epidermis. A hypoderm of large, roundish cells is developed underneath the epidermis on both faces of the involucre. The mesophyll is almost destitute of chlorophyll; it is homogeneous and traversed by wide, intercellular spaces, besides by several very small mestome-bundles.

### *The floral bracts.*

The cuticle and the epidermis exhibit exactly the same structure as observed in the involucre, while the hypoderm is absent from the ventral face and but slightly differentiated on that of the dorsal. The homogeneous, somewhat open mesophyll contains a little chlorophyll, and about seven very small mestome-bundles are located in the middle of this tissue.

### *The stem.*

The long stolons above ground and the flower-bearing stems show the same structure. They are nearly cylindric, slightly hairy, but perfectly smooth. We notice, also, here a wrinkled cuticle, covering an epidermis of relatively small cells of which the outer wall is distinctly thickened; none of the epidermal cells were transformed into secreting cells. Underneath the epidermis is a hypoderm of only one layer of very large, roundish cells, much larger than those of the adjoining cortex. This tissue, the cortex, consists of about fifteen strata, of which only the peripheral contain chlorophyll; the innermost layer is differentiated as a thin-walled endodermis, surrounding a continuous ring of about fifteen layers of very thick-walled stereome. Directly bordering on the stereome is a circle of twenty-four collateral mestome-bundles separated from each other by broad medullary rays; they are oval in cross-sections and contain both leptome and hadrome, the latter consisting of a few, but wide vessels. But there is no parenchyma-sheath and no mechanical support on the sides of these mestome-bundles or around the hadrome. The central pith is very thin-walled and open. Secreting cells abound in the cortex and in the pith.

### *The rhizome.*

The horizontal rhizome is cylindric, glabrous and smooth; towards the apex it is densely covered with sheathing, green leaves, and is not exposed to the light. Its free portion, behind the rosette of leaves, becomes soon deprived of both the epidermis and hypoderm, but protected by many layers of cork. The cortical parenchyma consists of about fifteen layers with wide intercellular spaces; the cells are filled with starch or contain a secretion of a reddish brown color. The very numerous mestome-bundles are narrow oblong in transverse sections, and are nearly all arranged in a circle separated from each other by rays of the very broad, central pith, which contains starch. The leptome occupies only a small portion of the mestome-bundles, and between this and the very prominently developed hadrome are several strata of cambium.

### *The root.*

All the roots were so far advanced that they showed only a secondary stage of growth. By the increase in thickness the tissues from epidermis to pericambium had been thrown off and replaced by some, five to six, layers of cork and a very large parenchyma of secondary cortex, filled with starch or sometimes interspersed with secreting cells. Towards the central cylinder the cells of the cortex decrease in size and the innermost layer shows somewhat the structure of a secondary endodermis by its darker color and its power to resist the effect of concentrated sulphuric acid. The central cylinder, however, shows a part of its original structure, viz: a circle of nine short hadromatic rays, each consisting of a few, narrow vessels (*H* in figure 6). These rays alternate with nine collateral mestome-bundles in which the vessels are quite wide (*V* in fig. 6), and mostly more thin-walled than the primordial. Several layers of cambial tissue (*C* in fig. 6) are developed outside the old vessels and inside the groups of leptome, where the secondary hadrome has become developed. A broad and compact pith occupies the inner part of the central cylinder, thus the structure of the root corresponds very well with that of the stem, if it were not for the presence of the primordial rays of hadrome between the collateral mestome-bundles.

### *Summary.*

Being an inhabitant of moist, saline localities our plant may, perhaps, be regarded as a Halophyte. The structural peculiarities of this category of plants has been studied to some extent, but as yet too little has been ascertained to enable us to draw the line between Halophytes and Xerophytes or even the Hydrophytes. Moreover, there are certain orders of plants in which the structural peculiarities appear as characteristic of the order and to some extent inherited, rather than being an expression of a certain mode of adaptation, such as the epharmonic characters.

Now in regard to *Anemiopsis Californica*, it certainly appears as if the structure may be defined more properly as simply "piperaceous" than either halophilous or xerophilous. The most conspicuous characters—the prominently developed hypoderm and the abundance of secreting cells throughout the various tissues—are in conformity with the general structure of the order rather than with the Halophytes, for instance, and these characters are very important. Then when we compare the tables of "leaf-anatomy of salt-marsh species" in Mr. Kearney's interesting paper on this subject,* we notice several points by which our plant differs from his salt-marsh species.

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* The plant covering of Ocracoke Island. Contrib. U. S. Natl. Herb., vol. v, Washington, 1900, p. 310.

Most of the species examined by this author possess isolateral leaves; several of these have hypodermal collenchyma or the mestome-bundles are supported by real stereome. On the other hand, Mr. Kearney observed a wrinkled cuticle and a like distribution of stomata on both leaf-surfaces, both of which characters, as we remember, are also to be observed in *Anemiopsis*. A similar result is reached when we compare the species examined by Professor Warming,* none of which possess such striking peculiarities as those characteristic of the *Piperaceæ*, nor do the features of his Halophytes in general agree with those of our plant; only a few points and of no particular interest or of seemingly great importance may be found common to both. As stated by Professor Warming, the lack of stereome seems to be characteristic of the Halophytes, so far as concerns their leaves, and only these have been examined. In this respect *Anemiopsis* would show some likeness to the Halophytes, since the leaves contain very little stereome and only near the midrib. But if we compare the other parts of the plant, the stem and the petiole for instance, we then observe this tissue to have reached a very high development, especially in the flower-bearing stems and the stolons.

It would, thus, appear as if *Anemiopsis* so far as concerns the structure, gives a better illustration of one of the several types of the *Piperaceæ* than of any specialized type modified in accordance with the environment, halophilous for instance.

Brookland, D. C., October, 1904.

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* Halofyt-Studier, Kgl. Danske vid. Selsk. Skr., 6th series, vol. viii, Kjöbenhavn, 1897, p. 175.

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *The Production of Pure Sodium Hydroxide for Laboratory Uses.*—On account of the danger in dissolving any considerable amount of metallic sodium directly in water, because of the very violent explosions that are likely to take place from an unexplained cause, even with bright metallic sodium, F. W. KÜSTER has devised a method for effecting this solution slowly by the help of moist air, and has thus obtained a very satisfactory and cheap caustic alkali solution. He places a bell-jar in a large, flat dish in which there is sufficient water to make a water-seal, and under the ball-jar he places a platinum, silver, or nickel dish, crucible, or wide-necked flask, as a receptacle for the caustic solution. Above the receptacle is placed upon a tripod a piece of nickel wire gauze, bent into a conical shape with its apex downward, and in the cone pieces of sodium are placed after the outer crust has been cut off. The sodium begins at once to deliquesce while bubbles of hydrogen escape through the water-seal, and the resulting sodium hydroxide solution drops as a very concentrated, oily liquid from the point of the cone into the dish below. The operation goes on until all the sodium has been used up, and at last certain impurities of the sodium remain upon the wire-gauze, so that this process gives a purer product than direct solution. The solution thus obtained is of about 40 per cent strength, and it may be kept absolutely free from carbonate.—*Zeitschr. anorgan. Chem.*, xli, 474. H. L. W.

2. *The Production of Magnetic Alloys from Non-Magnetic Metals.*—R. A. HADFIELD, who has produced the well-known non-magnetic alloy of iron and manganese known as "manganese steel," calls attention to the interesting fact that a magnetic alloy can be produced from the non-magnetic metals, copper, aluminium, and manganese. A sample of this alloy, which appears to have been prepared by Dr. F. Heusler, contains 60 per cent copper, 25 to 27 per cent manganese, 12 per cent aluminium, 6 to 7 per cent silicon, 0·5 to 1 per cent carbon and probably 0·5 per cent iron; but samples containing absolutely no iron had exactly the same magnetic properties. It has been found that no alloy of copper and aluminium is magnetic, hence it appears that the magnetic properties of the alloy are due to manganese, which, curiously enough, produces the non-magnetic alloy with iron. It is to be observed, however, that the alloy under consideration requires the presence of a certain amount of aluminium in order that it may be magnetic, and that with fairly constant contents of manganese amounting to 25 to 28 per cent, the maximum "magnetizability" is reached when 14 per cent of aluminium is present.—*Chem. News*, xc, 180. H. L. W.

3. *Ozobenzol.*—A product of the action of ozone upon benzol

was named and described by Renard a number of years ago, and the formula $C_6H_6O_6$ was then ascribed to it. **Harries** and **Weiss** have recently re-investigated this substance and find that its formula is $C_6H_6O_9$; that is, three molecules of ozone attach themselves to benzol, presumably at the points of double linking, according to Kekulé's theory. The compound forms a gelatinous mass when ozonized oxygen is allowed to act at 5–10° upon benzol. It is fearfully explosive, resembling iodide of nitrogen in this respect. When ice-cold water is placed upon the amorphous substance it assumes a crystalline modification which is also exceedingly explosive. It appears that the formation of this compound is a support to Kekulé's benzol theory.—*Berichte*, xxxvii, 3431. H. L. W.

4. *Concerning Emanium.*—Some time ago **Giesel** announced that he had found a new radio-active substance related to lanthanum, which was characterized by its remarkable action upon the blende screen. He has recently been able to compare the action of this "emanium" with Debierne's actinium, which is related to thorium, and finds that the two substances show no difference with the screen. He is still inclined to believe, however, that there may be a difference in the substances, on account of an apparent slight difference in the rates of decay of their induced activity, and also on account of the fact that three lines which the phosphorescence of his substance shows in the spectroscope have not been found with actinium.—*Berichte*, xxxvii, 2963. H. L. W.

5. *The School Chemistry;* by **Elroy Avery**. 12mo., pp. 423. American Book Company, 1904.—This new text-book for high schools and academies is noticeable for being more extensive in its scope, both in the descriptive and theoretical parts of the subject, than is usual with books of this class. The experiments introduced are numerous, more than 300 being given, and they appear to be very well chosen for the purposes of instruction. A particularly good feature of the book is the number and variety of arithmetical problems, and other thought-inducing questions, that are presented. Although the book is well up-to-date in its facts, since such recent topics as radio-activity are discussed, the treatment of chemical theories may be considered as somewhat old-fashioned. For instance, there appears to be no mention of ionization, although many electrolytic experiments are given, and although the "changing places" of atoms or groups in reactions is frequently alluded to. A few inaccurate or misleading statements have been noticed in the book, but these do not appear to be unduly numerous. It is to be hoped, since hydrogen was solidified several years ago, that the characterization of lithium as the lightest solid known will soon disappear from our text-books, because it is about seven times heavier than solid hydrogen. H. L. W.

6. *Application of Some General Organic Reactions;* by Dr. **Lassar-Cohn**. Authorized Translation, by J. **Bishop Tingle**.

12mo., pp. 101. New York, 1994 (John Wiley & Sons).—The topics discussed in this book are "Fixation of Hydrogen Atoms," "Modification of Reactions," "Improvement in Conditions of Reactions," and "Influence of Atoms and Atomic Complexes." These subjects are of importance, and have not received sufficient attention in other works. The simple and entertaining manner in which the book is written should make it of interest not only to the experienced chemist, but also to the beginner in organic research. T. B. J.

7. *Influence of Glass Walls of Geissler Tubes on Stratified Discharges in Hydrogen.*—E. GEHRCKE, of the Reichsanstalt, finds that the glass walls exert a marked influence on the length of such stratifications. Not only the curves drawn from measurements but the appearance of the stratifications in suitable tubes show this influence. To make the effect evident to the eye one side of the inner wall of a Geissler tube was covered with silver; this had the effect of changing the length of the stratifications. The inner walls were also covered in another case with a layer of phosphoric pentoxide, with the same result. The author refers the stratifications observed in open space in flames to an effect of secondary cathodes. The stratifications in Geissler tubes appear to be a chain of cathodes with dark spaces and light spaces; the potentials of which seem to form an arithmetical series, and each stratification hands on to the next as much negative electricity as it received from the previous one. Foundation for a suitable mathematical theory is discussed.—*Ann. der Phys.*, No. 13, 1904, pp. 509–530. J. T.

8. *Phosphorescence.*—P. LENARD and V. KLATT continue their researches on this subject. Among their interesting conclusions is the following: Stokes's law that the waves of excited light are always longer than those of the exciting light has not been sustained by analysis of the sixty-four fluorescent bands examined. If the range of the exciting and the produced light are compared, it is seen that the exciting light and the fluorescent bands often approach each other very nearly; sometimes coincide, but never overleap each other. Study was made of momentary and more or less permanent fluorescence and of their dependence on exciting conditions.—*Ann. der Phys.*, No. 13, 1904, pp. 425–484. J. T.

9. *Color Changes in Gold Preparations.*—The theory of electrical resonance has been applied by various observers to account for the phenomena presented by colloidal preparations of gold in reference to color. F. KIRCHNER and R. ZSIGMONDY have had in view especially Planck's work in this direction. Their results support in general Planck's theory. There were, however, noticeable lacunæ between the theory and the observations.—*Ann. der Phys.*, No. 13, 1904. J. T.

10. *Spectra of Hydrogen, Helium, Air, Nitrogen, and Oxygen in the Ultra Violet.*—With the aid of a quartz spectroscope, J. SCHNIEDERJOST has made a study of these gases. Comparison lines of platinum were employed. Two new lines of helium at

wave-lengths 2653·1 and 2644·9 were discovered which belonged to the first main series. Deslandres' nitrogen group which lies between wave-lengths 3009·6 and 2205·3 was investigated, and Deslandres' results confirmed. Seventy new lines of the line-spectrum of nitrogen were also measured. A number of new lines of oxygen were also discovered.—*Diss. Halle*, 1904. *Beiblätter, Ann. der Phys.*, No. 22, 1904. J. T.

11. *Pressure of Light.*—In a sealed communication to the R. Accad. dei Lincei in 1882, opened at the meeting of February 1, 1903, A. BARTOLI relates that certain experiments conducted in the year 1876 appeared to show that the pressure of light apparently confirmed by late experimenters does not really exist, and that there arises a certain resistance which a reflecting body encounters in a region of radiation, and which in the movement of a reflecting body would be shown in the body without a normal component in consonance with the second law of thermodynamics. He suspects further that the work for overcoming this resistance is changed into electric currents in the reflecting metal. These currents should be of measurable size. This suspicion was apparently confirmed by experiment. He mounted a strong circular disc upon the axis of a solid lathe. This disc had a circular highly-reflecting band which was insulated by dry wood soaked in oil. The band was cut and the two ends were connected to two rubbing insulated contacts and to a sensitive galvanometer. The velocity of revolution of a point on this band was 240–410 meters per second. When sunlight fell on the silvered band the thermo-electric effect was only $2·3^{mm}$ deflection if the disc was at rest. When the disc rotated in the dark there was no reflection. As soon as sunlight fell on the rotating disc the galvanometer gave a deflection of $42^{mm}$, and this deflection persisted while the sunlight remained. It disappeared when the sunlight was removed. When the revolution was reversed the deflection was reversed to $-32^{mm}$. A half speed gave a deflection of $20^{mm}$. These experiments were made in August and September, 1880, in the Technical Institute of Florence, and were so far as is known never resumed.—*Beiblätter, Ann. der Phys.*, No. 22, 1904. J. T.

12. *Notes on X-Light;* by WILLIAM ROLLINS. Pp. 400, plates 150, Boston, 1904.—This beautifully printed volume contains the arduous researches of a professional man who has devoted his evenings to what is perhaps the most baffling and trying of all physical research, experimentation on gases at low vacuo—trying both to physical endurance and to the spirit; for just as nature seems to be inclined to open her mysterious chambers, the glass apparatus and the mechanical apparatus employed in producing such vacuo breaks, and the course of experimentation has to be begun anew. The expenditure of time and money, in giving freely to physicians and surgeons the best means of producing and employing the X-rays, shown by this book is remarkable, especially when one reviews the history of the use of these rays and sees the endless effort to secure all

improvements in tubes or processes of regulation by patents. Following the method adopted by Faraday, the author relates both positive and negative results of his experiments. In the subject of rarified gases, especially at low pressures, this method in the present uncertainty of our knowledge is most useful; for, like the story of the Alpine climber who relates his attempts to scale some most difficult aiguille, it stimulates the imagination and leads to a consideration of all possible paths in the hope of finding, even through failure, a way to the summit; and in ultimate success, the first path-breaker should not be forgotten. In reading the list of contents of this volume one is surprised at the richness of suggestion. Every form of X-ray tube, of regulators and of exciters for such tubes, receives thought, and it is recognized by those who have followed Dr. Rollins' work that the present forms of the most enduring and most efficient tubes are the result of his work. Makers of such tubes have eagerly taken up his suggestions and by (we will charitably say) unconscious cerebration have taken credit to themselves. This is true also of the open construction of Ruhmkorf coils which the author fully describes in his book, and the employment of a hinged Faraday ring in the primary of such coils. This is a most efficient construction of a transformer both for X-ray work, for spectrum analysis, and for wireless telegraphy. No one in America appears to have had the experience of Dr. Rollins in exhausting X-ray tubes to their point of greatest efficiency. He points out many phenomena of absorption and occlusion of gases by the various terminals he employed, and by the glass walls of the enclosure which are now being studied quantitatively by various observers. This occlusion or absorption can under certain conditions reduce the pressure in an X-ray tube from one-thousandth of a millimeter to one two-thousandth. The mechanical skill shown in the plates of appliances for the employment of X-rays in surgery, which are collected at the end of the volume, would suffice alone to make this a notable work and a monument of altruism. J. T.

## II. GEOLOGY AND MINERALOGY.

1. *Indiana Geological Survey.* — W. S. BLATCHLEY, State Geologist. 28th Annual Report, 1903, 553 pp., with plates, maps and figures.—In addition to the statistical reports of the mine inspector, the gas supervisor, etc., the Indiana Survey Report for 1903 contains articles by T. C. Hopkins and A. F. Foerste on the Topography and Geological Formations of the state accompanying the new Geological Map; and a paper on the Stratigraphy and Paleontology of the Niagara, by E. M. Kindle. There is also a valuable table of contents of all of the geological literature published by the state of Indiana. The report of the state gas supervisor brings clearly to mind the great waste that has been caused by the careless treatment of the natural gas supply. The people of the state have finally been convinced that the gas sup-

ply is not inexhaustible. It is fast declining and the end is not far off. Most of the present drilling is done in territory abandoned years ago, and the average well now drilled would have been considered a failure ten years ago. The price of gas has increased fivefold in ten years and at the present time more pipeline is being taken out of the ground than put in it. Two large gas companies have entirely abandoned the city of Indianapolis.

2. *Geological Map of Indiana.* — A new geological map of Indiana has been published under the direction of W. S. Blatchley, state geologist, on a scale of four miles to the inch. This map is a compilation of all the stratigraphic work done in the state from 1895 to 1903 inclusive, while the actual work of preparation is by T. C. HOPKINS. Accompanying the map is a short description (77 pp.) of the topography of Indiana and of the chief geologic formations of the state. No attempt has been made to represent the rock structure underneath the heavy glacial deposits covering the northern part of the state for a distance of about forty miles.

3. *Geological Survey of New Jersey;* HENRY B. KÜMMEL, State Geologist. Vol. VI, 533 pp., 56 pls., 41 figs.—The latest volume of the New Jersey survey deals with the Clays and Clay Industry of New Jersey, and is written by Heinrich Ries and H. B. Kümmel, assisted by G. N. Knapp. The report deals with the occurrence, chemical and physical properties of clays, the stratigraphy of the clays and the method of their manufacture. A very complete set of fire brick tests has been made, particularly in reference to its refractoriness. A striking commentary upon the efficiency of the New Jersey survey is the fact that the clay maps of 1878 are found to be accurate in spite of the great development of the industry since that time.

4. *Recent Seismological Investigations in Japan;* by Baron DAIROKU KIKUCHI, Emeritus Professor of Mathematics Tōkyō Imperial University, Member and former President of the Imperial Earthquake Investigation Committee. Pp. ix + 120. 54 illustrations. Tokyo, 1904.—This volume, stamped "for private circulation only," was distributed at the Japanese exhibit of the recent exposition in St. Louis. As stated in the introduction, Japan is preëminently the land of earthquakes, and following the great Mino-Owari earthquake of October, 1891, in which over 7000 people were killed, the Imperial Earthquake Commission was established with a twofold object. First, to investigate whether there are any means of predicting earthquakes; and, secondly, to determine how to reduce the disastrous effects to a minimum. With characteristic Japanese insight and thoroughness the commission decided that the best way to attain its objects was first, possibly for many years, to study earthquakes in every relation, even such as might appear to have little or no bearing upon the immediate objects. The results of these investigations are given in sixteen publications in foreign languages, a list of which is given in the back of this volume. Among the more

noticeable features of the present volume are charts giving the time, distribution and periodicities of Japanese earthquakes for over a thousand years, and studies in the variations in magnetism, latitude and other physical changes as possibly having relations with the occurrence of severe earthquakes. For more than a decade astronomers have been familiar with the fact, rendered evident by long continued and refined astronomic observations in several parts of the world, that the earth's axis of rotation is not absolutely fixed, but that, on the contrary, the poles wander through a period of years in a complex path within a circle of a few hundred feet radius. Among other results the commission has found that the seismic activity of Japan presents a period of six and one-half years, and in the past nine years all the destructive earthquakes occurred exactly or very nearly when the latitude was at a maximum or minimum. J. B.

5. *Earthquakes, in the Light of the New Seismology;* by CLARENCE EDWARD DUTTON, Major U. S. A. Pp. xxiii+314, with 63 illustrations. New York (G. P. Putnam's Sons), London (John Murray), 1904.—This is volume 14 of "The Science Series," and while clear and readable throughout, nevertheless enters into all the chief problems related to earthquakes and is a volume which should be read by every teacher of physical geology. Previous to 1870 the studies published were with few exceptions little more than narratives of disasters. Since that time, largely through the labors of Ewing and Milne, who have more recently been joined by many other investigators, the subject has grown into an exact science which not only reveals the location of regions of unstability whether at the antipodes or even under the ocean, but which is throwing light upon such problems as the density and solidity of the earth's interior.

After discussing the nature and causes of earthquakes, the author devotes 48 pages to the subject of earthquake instruments, obviously an important topic since it is from these refined instruments that nearly all of our modern knowledge has come. Following this are 119 pages on the nature of earthquake waves and the deductions from them. This statement gives some idea of the complexity of the record and the involved messages it brings from the earth's interior and which are still far from being completely understood. The last part of the book discusses earthquake distribution and seaquakes. J. B.

6. *Minerals of Japan;* by TSUNASHIRO WADA, translated by TAKUDZI OGAWA. Pp. 144 with thirty plates. Tokyo, 1904.—Notwithstanding the comparatively limited extent of Japan and the fact that its resources are as yet only partially developed, the country has afforded a large number of mineral species, many of them of peculiar interest either because of their rarity or of the beauty of their crystallization. The volume before us gives an excellent summary of this subject and deserves careful study by all interested. Concise accounts of the species identified are given, with exact statement of locality and numerous analyses; a series

of fine heliotype plates give representations of notable specimens, for example, of the well known quartz twins, also the fine stibnite and topaz crystals. Among other Japanese minerals of especial interest may be mentioned crystallized danburite containing a considerable amount of magnesia (7·67 p. c.); datolite at Nobori, Hyuga Pr.; chalcopyrite of varied and unusual habit; axinite, etc. A new species, *naëgite*, is also described, as noted below.

7. *Brief notice of some recently described Minerals*—NAËGITE is a new silicate of uranium and thorium collected with fergusonite from the placer tin washings near Takayama, Mino province; it is described by T. Wada on p. 49 of the Minerals of Japan (1904, see above). It occurs in small spheroidal aggregates, also rarely in small crystals of pseudo-dodecahedral habit; these are probably tetragonal and isomorphous with zircon. The color varies between dark pistachio-green, greenish gray and brown or reddish brown; under the microscope it is transparent, grass-green and highly refractive, though also often nearly isotropic. The hardness is about 7·5 and the specific gravity 4·09; it has marked radio-activity. An analysis by T. Tamura afforded:

| $SiO_2$ | $UO_2$ | $ThO_2$ | $Ta_2O_5$ | $Nb_2O_5$ | $CeO_2$ | $Fe_2O_3$ | CaO | MgO | $H_2O$ |
|---|---|---|---|---|---|---|---|---|---|
| 34·89 | 28·27 | 16·50 | 7·00 | 4·10 | 1·59 | 1·60 | 1·71 | 0·57 | 3·12 = 99·35 |

The name is from the locality where the new mineral has been found, viz. Naëgi near Takayama.

TEALLITE is a new sulpho-stannate of lead from Bolivia, exact locality unknown; it is described by G. T. Prior. It occurs in thin inelastic, flexible and cleavable folia showing crystals face on the edges; the angles afforded by these proved that the mineral is orthorhombic and somewhat related in form to nagyagite. The hardness is 1 to 2 and the specific gravity 6·36; luster metallic, color blackish gray, streak black. The mean of two analyses gave: S 16·29, Sn 30·39, Pb 52·98, Fe 0·20 = 99·86. This yields the simple formula $PbSnS_2$ or $PbS.SnS_2$. Teallite is named after Dr. J. J. Harris Teall, Director-General of the Geological Survey of Great Britain and Ireland.

The same author has also analyzed carefully selected samples of franckeite and cylindrite, both from Poopó, Bolivia, the locality from which teallite may also very probably have been derived. The result is to give for franckeite the formula $Pb_5FeSn_3Sb_2S_{14}$ or $3\,PbSnS_2.Pb_2FeSb_2S_8$; for cylindrite, $Pb_3FeSn_4Sb_2S_{14}$, or $3\,PbSnS_2.SnFeSb_2S_8$. *Min. Mag.*, xiv, pp. 21–27, Oct. 1904.

PALMERITE is a new hydrated phosphate of aluminium and potassium described by Eugenio Casoria from a deposit of guano found in a large cavern at Monte Alburus near Controne, province of Salerno, Italy. It occurs in a white, amorphous pulverulent form, unctuous to the touch and resembling purified kaolin. An analysis yielded:

| $P_2O_5$ | $Al_2O_3$ | $K_2O$ | $Na_2O$ | $H_2O$(100°) | ign. | $Fe_2O_3$ | $NH_3$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|
| 37·10 | 22·89 | 8·04 | 00·3 | 7·87 | 21·29 | 1·17 | 0·61 | 0·37 = 99·37 |

The calculated formula is $HK_2\,Al_2(PO_4)_2 + 7H_2O$. *Att. Accad. Georgofilé* (5), i, July 3, 1904.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Annual Report of the Regents of the Smithsonian Institution*, S. P. LANGLEY, Secretary, *showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1903.* Pp. lxi, 376 with 124 plates. Washington, 1904.—This volume contains the usual account of the administrative activity of the Smithsonian Institution in its different directions. The work in one of these in particular, the International Exchange Service, is presented in a very interesting form. In an Appendix a striking exhibit is made of the extent to which this service has been developed; upwards of 150,000 packages were sent out to all parts of the world between July, 1902, and June, 1903, this work having nearly doubled in six years. The value of this service to the science of the country can hardly be overestimated. Another Appendix describes the additions to the National Zoological Park, with some interesting illustrations; still another gives a report of the work of the Astrophysical Observatory for the year ending June 30, 1903. It is interesting to note here that the bolographic work carried on showed the earth's atmosphere to have been more opaque than usual, the direct solar radiation having been reduced about 10 per cent on an average through the entire spectrum. It is also shown to be probable that the radiation has been decreased outside of the earth's atmosphere. A new determination of the temperature of the sun, based upon the distribution of the solar radiation in the spectrum, has yielded the result of 5,290° Centigrade above the absolute zero. As usual, the larger part of the volume of about 800 pages is given to the republication of a well-chosen series of scientific papers, showing the progress made in all departments of science. These are fully illustrated and form a most interesting series, which ought to be accessible to all intelligent people.

2. *Bulletin of the Bureau of Standards;* S. W. STRATTON, Director. Vol. I, No. 1, pp. 124. Washington, 1904 (Department of Commerce and Labor).—The Bureau of Standards, established some four years since, in addition to its regular testing work, the value of which is now thoroughly appreciated in the country, has recently undertaken the publication of occasional Bulletins. These will contain the results of investigations and researches carried on in connection with the Bureau, and which are likely to be of general interest in the country, either on the scientific or technical side. The Bulletins will be issued as often as they are required to present papers which are ready for publication. The first number, issued November 1st, contains eight articles. L. A. Fischer discusses a recomparison of the United States prototype meter; K. E. Guthe gives a study of the silver voltameter, and also describes fibers resembling quartz made from asbestos (amphibole) and steatite; F. A. Wolff discusses the so-called international electrical units; P. G. Nutting has papers on the spectra of mixed gases, on secondary spectra, and

on new rectifying effects in conducting gases; C. W. Waidner and G. K. Burgess give results of determinations of the temperature of the arc varying from 3690° to 3720° C., according to the form of pyrometer employed.

3. *National Academy of Sciences.*—The autumn meeting of the National Academy was held in the buildings of Columbia University, New York city, on November 15 and 16. The following is a list of papers presented:

W. K. **Brooks**: On the affinities of the Pelagic Tunicates.

W. K. **Brooks** and S. **Rittenhouse**: The life history of *Turritopsis.*

W. K. **Brooks** and R. P. **Cowles**: *Phoronis architecta*, its anatomy, life history, and branching habits.

**John Trowbridge**: On the electrical resistance of a vacuum.

**Franz Boas**: Psychic associations in primitive culture.

M. I. **Pupin**: Time electrical impulses.

C. **Barus**: The occurrence of maxima and minima of atmospheric nucleation in approximate coincidence with the winter and summer solstices respectively.

L. A. **Bauer**: The system of magnetic forces causing the secular variation of the earth's magnetism.

R. H. **Chittenden**: The influence of low proteid metabolism on the formation and excretion of uric acid in man.

**Edward** M. **Morley**: Note on the theory of experiments to detect the second power of the aberration of light. Also, Report of a repetition of the Michelson-Morley experiment on the drift of the earth through the luminiferous ether.

C. S. **Peirce**: On topical geometry.

N. **Yatsu**: An experimental demonstration of the formation of centrosomes *de novo.*

T. H. **Morgan**: An analysis of the phenomena of organic polarity.

E. B. **Wilson**: Experiments on prelocalization in the annelid ovum.

C. E. **Mendenhall**: The absolute value of the acceleration of gravity determined by the ring-pendulum method.

R. S. **Woodward**: The double suspension pendulum for measuring the acceleration of gravity.

**Theo. Holm**: The genus Claytonia,—morphological and anatomical studies.

**Charles** S. **Hastings**: A determination of the dispersive power of the human eye.

**Chas.** F. **Chandler**: The air in the Subway in New York.

W. H. **Dall**: Biographical memoir of Charles Emerson Beecher.

**Edgar** F. **Smith**: Biographical memoir of Robert E. Rogers.

4. *American Association for the Advancement of Science.*—The fifty-fourth annual meeting of the American Association was held in Philadelphia, in the buildings of the University of Pennsylvania, during the week from Dec. 27 to 31. The various affiliated societies also held their meetings at the same time and place. This is the third "Convocation week" that has been observed at this season of the year.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. VII.—*The Isomorphism and Thermal Properties of the Feldspars;* by ARTHUR L. DAY and E. T. ALLEN. (With Plate I.)

THE investigation here recorded is the first chapter in a rather comprehensive plan for the study of the rock-forming minerals at the higher temperatures. In its broader outlines at least, it is by no means a new plan. Mr. Clarence King and Dr. George F. Becker were inspired by a desire to reach the mineral relations from the experimental side, which is recorded in the very earliest records of the U. S. Geological Survey, and much of the remarkable ground-breaking work of Professor Carl Barus was undertaken in furtherance of a carefully prepared scheme of research along these lines. The matter has been advanced but little in the intervening years. The present renewal of the effort in this direction is again due to Dr. Becker and has the benefit of his wide field experience and enthusiastic and effective coöperation throughout.

In October, 1900, one of the authors was called from the Reichsanstalt to equip a laboratory in the U. S. Geological Survey in which the exact methods and measurements of modern physics and physical chemistry should be applied to the minerals. The ultimate purpose was geological, to furnish a better basis of fact for the discussion of the larger problems of geology, but it appeared highly probable also that a quantitative study of the thermal phenomena in this class of substances would offer new relations of intrinsic interest and of considerable theoretical value. This inference has been happily substantiated quite recently through the publication by Tammann of an extended treatise on melting and crystallization,* in which he offers some very interesting speculations on the conditions of equilibrium for substances above and below the melting temperature under different pressures. The behavior of crystalline minerals, which melt at temperatures considerably higher than he was able to command, offers peculiarly advantageous opportunities for verifying the truth of his inferences and of contributing further to the knowledge of this most important change of state of matter.

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* Tammann, "Krystallisiren und Schmelzen." Leipzig, 1903.

*Temperature Measurements.*—It is only a short time since it became possible to measure even moderately high temperatures with certainty and to express them in terms of a well-established scale. Temperature is a peculiar function in that it is not additive. Two bodies, each at a temperature of 50°, can not be united to obtain a temperature of 100°, nor can any number of bodies, at a temperature of 50° or below, give us information about the temperature 51° or above. Furthermore, temperature is not independently measurable: we can only measure phenomena like the expansion of gases or the conductivity of platinum wire or the energy of thermal radiation, which we have good reason to suppose will vary with the temperature uniformly or according to a known law.

The measure of temperature now generally accepted as standard is the expansion of hydrogen gas between the melting point of ice and the normal boiling point of water, divided into 100 equal increments or degrees. Temperatures above this point* have been determined by continuing the expansion of hydrogen or nitrogen in the same units, as far as it has been found possible to provide satisfactory containing vessels for the expanding gas. Such determinations are then rendered permanent and available for general use by establishing fixed points, such as the melting temperatures of easily obtainable pure metals, at convenient intervals. Beyond 1150° no trustworthy gas measurements have been made and we have therefore no standard scale. For higher temperatures it is usual to select some convenient phenomenon which is measurable up to the temperature desired, to compare it with the gas scale as far as the latter extends and then to continue on the assumption that the law of its apparent progression below 1150° will continue to hold above that point. In this way we obtain degrees which, if not identical with the degrees of the gas scale, approximate very closely to them and can receive a small correction if necessary, whenever the gas scale shall be extended or another scale substituted.

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* To 600°, Chappuis et Harker, Travaux et mémoires du bureau international des poids et mesures, xii, 1902. To 1150°, Holborn and Day, Ann. der Physik, ii, 505, 1900; English translation, this Journal [4], x, 171, 1900.

The application of measurable high pressures at the higher temperatures has never been successfully accomplished, and until something can be done in this direction, our knowledge of the rock-forming minerals and in fact all the generalizations relating to equilibrium between the states of matter, which have been established for moderate temperatures, must be regarded as more or less tentative and subject to eventual revision. We have been accustomed to assume, both in geology and physics, with rather more confidence than scientific experience justifies, that established relations for ordinary temperatures and pressures will hold in comparable ratio for the higher temperatures and pressures also. Experimentation under extreme conditions is slow and technically difficult, and it is therefore not strange that simple relations which are verifiable within easily accessible conditions should now and then be accorded the dignity of natural laws without sufficient inquiry into the more remote conditions.

*General Plan.*—Our plan on entering this field was to study the thermal behavior of some of the simple rock-making minerals by a trustworthy method, then the conditions of equilibrium for simple combinations of these, and thus to reach a sound basis for the study of rock formation or differentiation from the magma. Eventually, when we are able to vary the pressure with the temperature over considerable ranges, our knowledge of the rock-forming minerals should become sufficient to enable us to classify many of the earth-making processes in their proper place with the quantitative physicochemical reactions of the laboratory.

*Relation to Geological Research.*—The relation which this plan bears to general geological research may perhaps be expressed in this way. Geological field research is essentially a study of natural end-phenomena, of completed reactions, with but a very imperfect record of the earlier intermediate steps in the earth-making processes. The records of the splendid laboratory experiments in rock synthesis which have already been made are also of this character. The final product has been carefully studied, but the temperatures at which particular minerals have separated out of the artificial magma, and the conditions of equilibrium before and after such separation, have not been determined. In fact, except for a limited number of determinations of the melting points of natural minerals, no exact thermal measurements upon minerals or cooling magmas have been made, and it is in this direction that a beginning is to be attempted. The temperatures of mineral reactions under atmospheric pressures are nearly all within reach of existing laboratory apparatus and methods.

*Existing Methods.*—Furthermore, the methods which have been used in determining these mineral melting points seem to the authors to be open to serious objection both in principle and in application. They depend, almost without exception, upon the personal judgment of the observer and not upon the actual measurement of any physical constant. For this reason perhaps more than any other, the results obtained by different observers upon the same mineral from the same source do not agree within considerable limits, much larger than can be properly ascribed to impurities in the specimens. Familiar examples will best illustrate this point. Among the determinations of the mineral melting points, two have received much more general acceptance than others;—those of Joly* and of Doelter.†

The melting temperatures which they obtained for some of the typical feldspars are as follows:

| | Meldometer Measurement. | | Thermoelectric Measurement. | |
|---|---|---|---|---|
| | Joly, 1891; | Cusack, 1896. | Gas Furnace. Doelter, 1901. | Electric Furnace Doelter, 1902. |
| Microcline | 1175° | 1169° | 1155° | 1155° |
| Albite | 1175 | 1172 | 1103 | 1110 |
| Oligoclase | 1220 | | 1110 | 1120 |
| Labradorite | 1230 | 1235 | 1119 | 1125 |
| Anorthite | | | 1110 | 1132 |

The determinations agree in recording higher melting points toward the calcic end of the series, but the differences between corresponding melting points by the two methods is greater than the observed differences between different feldspars.

Joly's method was novel. He stretched a thin strip of carefully prepared platinum foil between suitable clamps, placed a few grains of the powdered mineral upon it and mounted a small microscope above, so as to be readily trained on any part of the strip. The foil was then heated by an electric current which could be very gradually increased, and the temperature measured from the linear expansion of the strip at the moment when the observer at the microscope noticed the first signs of melting. The author of this method was able to obtain concordant results with it to within about 5° C., but differences several times greater than 5° appeared in the observations made by one of us‡ with the Joly apparatus, unless the grains were prepared with the greatest care and all the observations made by the same observer. The size and form of the grains, the care used in locating them exactly in the middle of the strip, every draught of air, but most of all the judgment of the observer as to when the substance appeared to melt, all entered into the result to a very considerable degree. And there is another source of error with which we afterward became familiar, which may serve to account for the very large differences between Joly's results and our own later values with some of the well-known minerals, though not with all. In certain of the minerals, after melting, the resistance to change of shape due to viscosity is of the same order of magnitude as that due to the rigidity of the crystal just before melting, a fact which may well have led to large errors of judgment in this method of detecting melting points.

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* J. Joly, Proc. Royal Irish Acad., iii, 2, p. 38, 1891. R. Cusack, Proc. Royal Irish Acad., iii, 4, p. 399, 1896.

† C. Doelter, Tschermak, Min. u. Petr. Mitth., xx, p. 210, 1901; xxi, p. 23, 1902.

‡ Day.

The possibility of working very expeditiously with minute quantities of a substance led us to study this method with great care, and we were fortunate enough to possess an instrument of Prof. Joly's own model made by Yeates & Son, Dublin, but the results obtained with it, even under most favorable conditions, are more in the nature of personal estimates than of exact measurements of the change of state. Its value for qualitative study, and in cases where only a very minute quantity of a substance is available, is unquestioned.

Doelter has employed electric furnaces modeled after that in use at the Reichsanstalt by Holborn and Day for the determination of the melting points of the metals, measured his temperatures with thermoelements, and used several grams of material in his determinations, but he also judged of the approach of the melting point by the appearance of the charge and usually recorded two temperatures, the first approach of viscous melting, and the point where the material appeared to become a thin liquid.

*Detailed Plan.*—We determined from the first to get rid of this personal factor. However carefully such observations may be made, and however well supported by the reputation of a particular scientist for skillful and exact work, they can not have a permanent value. Melting points of pure minerals are not different, in principle at least, from the melting points of other chemical compounds or of metals. They occur at less accessible temperatures and involve some complicating phenomena, as we shall see presently, but the change of state of a solid crystalline mineral to a liquid must of course be defined by an absorption of heat. Whether the appearance of the mineral charge in the furnace will offer a trustworthy index through which to locate this absorption, may well be expected to differ with different substances. Nearly all observers have recorded the fact that many substances of this class remain very viscous after melting and that the transition is not well marked in the appearance of the material.

We therefore planned an apparatus* which should be as sensitive as possible to heat changes over a long range of temperatures, and then prepared to examine the thermal behavior of simple minerals of natural or artificial composition when gradually heated or cooled. Changes of crystalline form (Umwandlungen) or of state (melting and solidifying) must involve a more or less sharply marked absorption or release of heat and be recorded as breaks in a smooth curve in the same way as in the determination of metal melting points or the singularities of any of the well-known chemical compounds at lower temperatures.

*First Group of Minerals Investigated.*—The particular group of minerals chosen for the first investigation was the soda-lime feldspar series, and orthoclase (microcline). The reasons for this choice will be fairly obvious. Aside from its being altogether the most important group of rock-forming minerals, unusual interest has been attracted to it through Tschermak's theory that these feldspars bear a very simple relation to one another, that they are (orthoclase excepted of course) in fact merely isomorphous mixtures of albite and anorthite. This hypothesis has given occasion for serious and extended study both from the optical and thermal sides.

A complete review of the literature of the feldspars will not be attempted here. Although opinion is still somewhat divided,† it is probably fair to say that the optical researches have failed definitely to establish or disestablish the isomorphism of the albite-anorthite group, and that it is somewhat uncertain whether conclusive evidence will be obtained by optical means alone. Investigation from the thermal point of view has been even less satisfactory by reason of the subjective methods employed, to which reference has already been made, though the recorded results indicate with reasonable unanimity that the melting point of anorthite is above that of albite and that the intermediate feldspars will probably fall between the two.‡ Beyond this conclusion, the great body of evidence is more or less contradictory and sometimes controversial in character.

*Orthoclase (preliminary).*—Somewhat unluckily, our measurements began with natural orthoclase (microcline) from

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* For a detailed description of this apparatus see Day and Allen, Phys. Rev., xix, p. 177, 1904.

† Fouqué et Lévy, Synthèse des Minéraux et des Roches, p. 145, 1882. C. Viola, Tschermak's Min. u. Petr. Mitth., xx, p. 199, 1901. Lane, Journ. Geol. XII, ii, p. 83, 1904. J. H. L. Vogt — Die Silikatschmelzlösungen. Christiania, 1903.

‡ J. H. L. Vogt, loc. cit., p. 154, expresses the opinion that the soda-lime feldspars will be found to fall under Type III of Roozeboom's types of isomorphous series, with a minimum between anorthite and albite. (See p. 134, seq.)

Mitchell Co., North Carolina, a quantity of which was placed at our disposal by the U. S. National Museum. The material was powdered so as to pass readily through a 100-mesh sieve, and placed in $100^{cc}$ or $125^{cc}$ platinum crucibles, sometimes open and sometimes covered, in charges of from 100 to 150 grams. These charges were heated slowly in the electric furnace from 600° to above 1400° C., but, although the thermal apparatus was sufficiently sensitive to detect an unsteadiness of a tenth of a degree with certainty, not the slightest trace of an absorption or release of heat was found. The charge at the beginning of the heating was a dry crystalline powder, which was prodded from time to time with a stout platinum wire to ascertain its condition as the heating progressed. At about 1000° traces of sintering were evident, at 1075° it had formed a solid cake which resisted the wire, at 1150° this cake had softened sufficiently to yield to continued pressure and at 1300° it had become a viscous liquid which could be drawn out in glassy, almost opaque threads by the wire. Under the microscope the opacity was seen to be due to fine, included bubbles, the material being entirely vitreous. The cooling was equally uninstructive; the vitreous mass solidified gradually without recrystallization or the appearance of any thermal phenomenon. Frequent repetition with fresh charges and varied conditions added nothing to our knowledge of the melting temperature, and the matter began to look very unpromising.

We also reheated charges of the resulting glass which was sometimes repowdered and sometimes in the cake as it had cooled. But except to observe that the glass powder began to sinter earlier (800°), no new facts appeared.*

Then we tried by various means to recrystallize the melted orthoclase. We mixed crystalline powder with the glass, we applied successive quick shocks to the cooling liquid for several hours with an electric hammer below the crucible, we varied the rate of cooling and even tried rapid see-sawing between 800° and 1300°. We circulated air, water vapor, and carbonic dioxide through the charge throughout the heating, and finally introduced a rapid alternating current sent directly through the substance while cooling, but no trace of crystallization resulted. An extremely viscous, inert mass always remained which gradually hardened into a more or less opaque glass. It appeared somewhat translucent if very high temperatures had been reached, but was never clear.

Following orthoclase, a number of specimens of natural albite were tried under similar conditions and with entirely similar results.

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* These sintering temperatures varied within considerable limits with the fineness of the material and therefore serve only in a very rough way to define the state of the charges.

Later on, when more experience had been acquired, these minerals were taken up again and a satisfactory explanation for their behavior was found. But for the moment all the defining phenomena appeared to be so effectively veiled by some property, presumably the viscosity, that we were constrained to look about for some simpler compound which should give us a better insight into the behavior of mineral glasses and their thermal relations, and to lay aside the feldspars until they could be more successfully handled.

This outline of our unsuccessful experiences is given here in some detail, in order to show the actual difficulties which confront the student in working with the feldspars, in the face of which it is certainly not surprising that uncertain and contradictory conclusions have been reached.

*Borax.*—The substance chosen for this preliminary work was ordinary anhydrous borax (sodium tetraborate). We chose this merely because it was a simple glass and unlikely to undergo chemical change. It is easily obtainable pure and its thermal phenomena are within easy reach. The study of borax proved to be most instructive. It gave us an effective insight into the behavior of this class of substances, and in particular served to define the phenomena of melting and solidifying in substances which undergo extreme undercooling and which recrystallize with difficulty or not at all. The results of this study of borax were therefore of much interest in themselves and were given in a paper before the National Academy of Sciences at its spring meeting in Washington last year (April 21, 1903), but were not printed at that time.

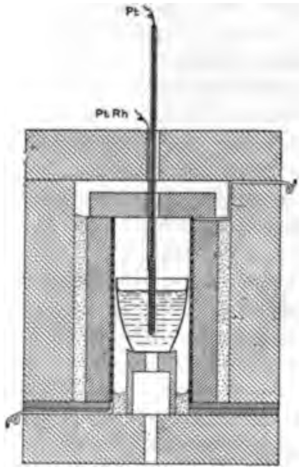

Fig. 1.

The borax glass upon which our measurements were made was prepared in the usual way by heating the crystals until the water of crystallization had been driven off and the viscous mass was reasonably free from bubbles. If the borax is pure, the anhydrous product, when cooled, is a brilliant, colorless glass, isotropic, of conchoidal fracture; and specific gravity 2·37. The specific gravity was determined in the fraction of kerosene boiling above 185° C. About 100 gr. of this glass were then broken up and placed in a platinum crucible in the electric furnace. The thermoelement was placed in position

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as indicated in fig. 1, the heating current properly regulated and observations of the temperature made at intervals of one minute, while the glass softened and passed gradually over into a thin liquid (800°). Then the current was reduced and the cooling curve observed in the same way. These observations gave an unbroken curve both for the heating and cooling, as in the case of all the glasses,* without a definite melting or solidifying point, although the arrangements for detecting an absorption or release of heat were very sensitive. Prodding at intervals with a platinum rod showed the change to be perfectly gradual from a clear, hard cake through all degrees of viscosity to a fairly thin liquid and back again. This observation is of considerable interest as showing that the absence of bounding phenomena between the cold glass which fulfils the mechanical conditions for a solid very perfectly, and the liquid, is not confined to mixtures of complicated chemical composition, but is exhibited also by true chemical compounds of undoubted purity. It is therefore not conditioned by composition but by the physical nature of the substance. Having verified this behavior of anhydrous borax by several repetitions of the experiment, various disturbing influences were applied to the slowly cooling liquid in the hope that some temperature

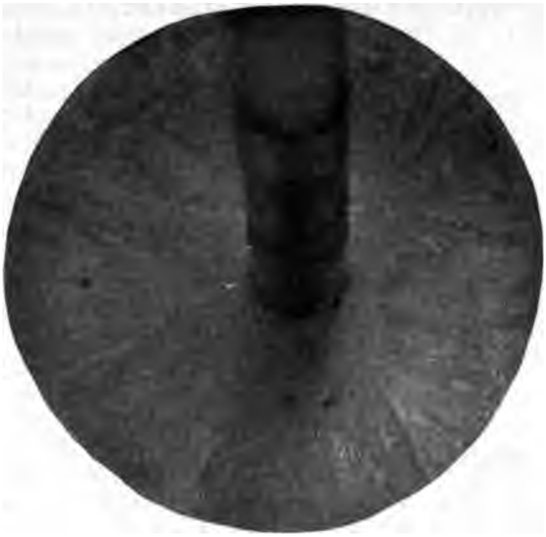

FIG. 2.

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* See Tammann, loc. cit., also Roozeboom "Die heterogenen Gleichgewichte, etc." Braunschweig, 1901.

or range of temperature would be found within which the vitreous condition would prove unstable and crystallization be precipitated. The jar produced by an electric hammer pounding upon the outside of the furnace during cooling proved to be sufficient to bring down the entire charge as a beautiful crystalline mass of radial, fibrous structure, brilliant luster, rather high refractive index and increased volume. The photograph (fig. 2) will give some idea of the appearance of the anhydrous crystalline borax in the crucible. Its specific gravity proved to be 2·28 as compared with 2·37 for the glass, a somewhat unusual relation,* which may in part account for the quasi-stability of the vitreous form during cooling.

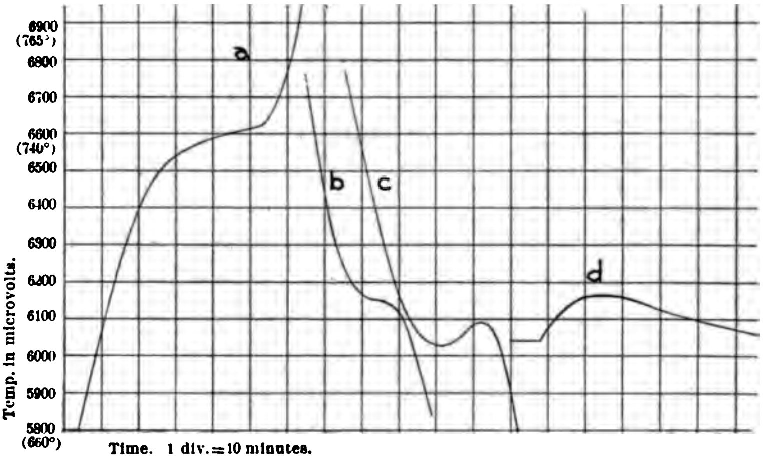

Fig. 3.

Observations were then undertaken upon the crystalline borax with a thermoelement as before, to determine the melting temperature and solid modifications if such existed, but none of the latter were found. The charge melted uniformly at 742° and the melting point was well defined. A curve showing the minute-to-minute observations on the crystalline borax between the temperatures 660° and 765° is shown in the adjoining figure (fig. 3, *a*).

Having determined the melting point of crystalline anhydrous borax satisfactorily, we examined more closely into the conditions under which it solidified. As has been said, if the melted charge was allowed to cool slowly, undisturbed, no return to the crystalline state occurred. It merely thickened into a transparent glass without releasing the "latent" heat which it had taken on in melting (fig. 5, *b*). If it was subjected to the jarring produced by the electric hammer on the furnace wall, it cooled down a few degrees below the melting point and then began to crystallize, the heat of fusion was set free and a rise in temperature or hump immediately appeared upon the cooling curve as shown in the figure (fig. 3, *b*, *c*, *d*). Up to this point the phenomenon differs but little from the usual behavior of liquids which undercool in solidifying. We then varied the experiment by first cooling quietly to about 100° below the melting point and then introducing a few crystal fragments or starting the pounding. Crystallization and release of the latent heat followed at once. In fact over a range of some 250° immediately below the melting point it proved to be within our power to precipitate the crystallization of the undercooled mass entirely at will. It was even possible to cool the melted charge quietly down to the temperature of the room and remove it from the furnace as a clear glass, then, on a subsequent day, to reheat to some point in this sensitive zone and pound judiciously, when crystallization would at once begin, marked by the release of the latent heat of the previous fusion as before (fig. 4, *a* and *b*). The accompanying curves show the situation clearly. Curves *aa′* and *bb′* (fig. 5), were obtained from charges of crystalline and vitreous borax, respectively, of exactly equal weight, which were cooled and reheated in the same electric furnace under like conditions. The radiation from the furnace for like temperature conditions will also be practically the same, so that the more rapid rate of cooling and of reheating in the crystalline charge indicates a much smaller specific heat than for the vitreous form.

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* Tammann. Loc. cit., p. 47 et seq.

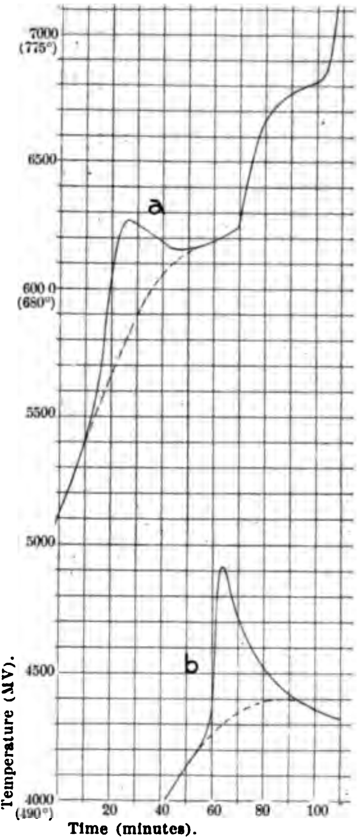

Fig. 4.

From the point of view of the usual definition of the solidifying point of a substance, a difficulty confronts us here: (1)

we were able to vary the beginning of solidification (crystallization) at will over a range of 250°, and (2) the temperature to which the charge rose after the undercooled liquid had begun to crystallize did not reach the melting point although once crystallization was induced only 10° below it in a furnace of constant temperature. The rapidity with which the crystallization and the accompanying release of the latent heat go on, depends in part upon the rate of cooling and the character of the disturbance which has been applied, i. e., upon accidental rather than characteristic conditions. It thus happens that the amount of the heat of fusion and its slow rate of liberation in the case of liquids which can be greatly undercooled and become very viscous, may be such as to deprive it of its usual significance as defining a solidifying point. It is, of course, a consequence of the phase rule that the solidifying temperature of an undercooled liquid is established, if only equilibrium between solid and liquid (and vapor) is reached before complete solidification is accomplished, but equilibrium *is not necessarily attained* during solidification, and the devices usually employed (sowing with crystals, agitating) are often totally inadequate to bring it about. The temperature to which a crystallizing liquid rises after undercooling is not necessarily constant or in any way related to the melting point, and is therefore not, in general, entitled to be regarded as a physical constant.

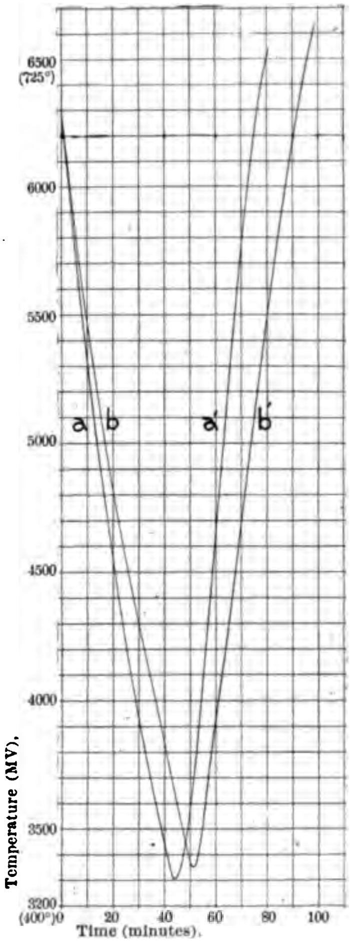

FIG. 5.

We then endeavored to ascertain whether the unstable domain had a lower limit also. For this purpose we mixed a quantity of the crystals with the glass and powdered them together to about the fineness represented by a 150-mesh sieve and heated them very slowly. In this condition the glass proved to be very unstable and crystallized readily with a rapid release of its latent heat at about 490°. Very slow heating (10 min. per 1°) gave a temperature a few degrees lower, but such variations as could be applied within the period of a working day did not suffice, under the most favorable conditions, to change this temperature materially. The first evidence of molecular mobility in borax glass, shown in the sticking together of the finest particles (sintering), and the first traces of crystallization and release of latent heat, appeared consistently at about 490–500°. Still a third phenomenon attracted our attention to this temperature. On every occasion when borax glass was heated rapidly, either powdered or in the solid block, a slight but persistent absorption of heat appeared in this same region and continued over some 20°, after which the original rate of heating returned. We were entirely unable to explain an *absorption* of heat in an amorphous substance under these conditions except by assuming an actual change of state to exist between amorphous glass and its melt, in which case the absorbed heat would reappear somewhere upon the corresponding cooling curve,—which it failed to do. We then reasoned that any assumed change in the molecular structure which would account for an absorption of heat would also be likely to cause an interruption in the continuity of the curve of electrical conductivity, and the relative conductivity was determined throughout this region; but no such interruption appeared.

Finally the matter was abandoned. The evidence did not appear sufficient to establish any discontinuity in the cooling curve of the glass, so long as no crystallization took place.

When these relations had been clearly established, we turned again to the feldspars.

It became clear very early in the investigation that only artificially prepared and chemically pure specimens would be adequate for our purpose. Each of the end members of the series, anorthite and albite, as found in nature, is always intermixed with some quantity of the other, while the intermediate members generally contain iron and potash, and all are liable to inclusions.

There was nothing new in this plan: Fouqué and Lévy* had demonstrated the possibility of making pure feldspars by chemical synthesis and had studied their optical properties some years ago. We undertook to prepare much larger quantities than they (200 grams), and to make a careful study of their heating and cooling curves under atmospheric pressure, the conditions under which anorthite and the plagioclases crystallize, the relations between the amorphous and crystalline forms, the sintering of crystalline and vitreous powders, in short, their entire thermal behavior, as we had done with the borax. At the same time it was our purpose to make careful determinations of the specific gravities of both the vitreous and the crystalline products, analyses of such portions as might be of special interest, and also to prepare microscopic sections wherever they were likely to throw light on the relations involved. The latter, after preliminary examination, were very thoroughly studied by Prof. J. P. Iddings of the University of Chicago, whose large petrographic experience with mineral crystallites makes his judgment of exceptional value.[*]

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* Synthèse des Minéraux et des Roches, loc. cit.

The constituents used in our syntheses were precipitated calcium carbonate, anhydrous sodium carbonate, powdered quartz (selected crystals) and alumina prepared by the decomposition of ammonium alum. None of these contained more than traces of impurities, if we except the quartz, in which 0·25 per cent of residue, chiefly oxide of iron, was found after treatment with hydrofluoric and sulphuric acids. All but the calcium carbonate were carefully calcined and cooled in a desiccator before weighing. To obtain a homogeneous product, the weighed constituents were mixed as thoroughly as possible mechanically, and heated in large covered platinum crucibles ($100^{cc}$ capacity) in a Fletcher gas furnace.[†] After some hours heating, during which the temperature usually reached 1500° or more, the product was removed from the furnace, cracked out of the crucibles, powdered, passed through a "100-mesh" sieve and then melted again. This process probably gives a fairly homogeneous mixture, though a third fusion in the resistance furnace was generally made before determining the constants.

We prepared in this way albite (Ab), anorthite (An) and the following mixtures of the two: $Ab_1An_5$, $Ab_1An_2$, $Ab_1An_1$, $Ab_2An_1$, $Ab_3An_1$, $Ab_4An_1$. All of these were obtained in wholly or partially crystalline form, by crystallization from the melt, except albite. The syntheses were controlled by analyses of a number of the products, the results of which are appended.

ANALYSES OF ARTIFICIAL FELDSPARS.

| | An | | $Ab_1An_5$ | | $Ab_1An_2$ | | $Ab_2An_1$ | |
|---|---|---|---|---|---|---|---|---|
| | Found. | Calculated. | Found. | Calculated. | Found. | Calculated. | Found. | Calculated. |
| $SiO_2$ | 43·33 | 43·28 | 47·10 | 47·18 | 51·06 | 51·30 | 60·01 | 59·81 |
| $Al_2O_3$ | 36·21 | 36·63 | 34·23 | 34·00 | 31·50 | 31·21 | 24·95 | 25·47 |
| $Fe_2O_3$ | ·29 | .... | ·15 | .... | ·22 | .... | ·29 | .... |
| CaO | 20·06 | 20·09 | 17·00 | 16·93 | 13·65 | 13·68 | 7·09 | 6·98 |
| $Na_2O$ | ·11 | .... | 1·74 | 1·87 | 3·68 | 3·79 | 7·79 | 7·73 |
| | 100·00 | | 100·22 | | 100·11 | | 100·13 | |

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[*] See Pt. II of the complete paper, Publications of the Carnegie Institution of Washington.

[†] Buffalo Dental Company, No. 41A. A Fletcher furnace of this type, with ordinary city gas pressure and a small blast motor, will melt all of the feldspars.

*Anorthite.*—Of the whole series of feldspars, this member is in many respects the simplest to deal with. It is of relatively low viscosity when melted and crystallizes easily, very rapidly, and always in large, well developed crystals. A 100-gram charge crystallized completely in ten minutes. Sudden chilling gave a beautiful clear glass entirely free from bubbles, somewhat slower cooling usually resulted in a partial crystallization from few nuclei, the crystals being always large. In appearance it resembles the natural mineral in every respect. Its hardness is also equal to that of natural anorthite. Thin sections show good cleavage, and twinning according to the albite law is frequent. The extinction and other microscopic characteristics are as well marked as in natural specimens.

The heating curve of crystalline anorthite is perfectly smooth except for the single break which marks the melting point. No trace of a second crystalline form (Umwandlung) appeared in this or any other of the feldspars within the temperature range of the observations (300°–1600°). Some undercooling always occurs in solidification even if the rate of cooling is slow, but it is less, under like conditions, with anorthite, than with any other member of the series. The heating curve of the glass shows a strong evolution of heat which may occur as low as 700°, when crystallization takes place. The melting point of crystalline anorthite was determined by three different thermoelements upon two different mineral preparations. It will be seen from the appended table that the determinations agree remarkably well.

ANORTHITE.

First Preparation.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Oct. 7, 1903 | A | 15939 | 1534° | solid charge, open crucible. |
| " " " | A | 15914 | 1532 | " " |
| " 10 " | A | 15878 | 1530 | covered crucible. |
| " " " | No. 3 | 16074 | 1533 | " " |
| " " " | 3 | 16058 | 1532 | " " |
| " " " | 3 | 16068 | 1532 | " " |
| " " " | 2 | 16095 | 1532 | " " |
| | | Mean | 1532° | |

Second Preparation.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Jan. 16, 1904 | A | 15860 | 1532° | covered crucible. |
| " " " | A | 15864 | 1532 | |
| " 20 " | No. 3 | 15960 | 1533 | |
| " " " | 2 | 16102 | 1532 | |
| " " " | 2 | 16092 | 1532 | |
| Mch. 31 " | 3 | 15932 | 1531 | 1st & 2d preparations together. |
| | | Mean | 1532° | |

Melting temperature 1532°.

The close agreement of these determinations is of very considerable significance with reference to the method of temperature measurement employed. It will be remembered that the established temperature scale ends at 1150° and that temperatures beyond that point are extrapolated with the help of some trustworthy phenomenon which varies with the temperature. We chose for this purpose the thermoelectric force developed between pure platinum and platinum alloyed with 10 per cent of rhodium. Now the constants of such thermoelements will usually differ among themselves and require to be determined for each element by calibration with the gas thermometer or with the melting points of the metals.* It therefore offers an excellent test of the value of the extrapolation if some sharp melting point can be found in the extrapolated range to serve as a point of reference. The melting point of crystalline anorthite serves this purpose exceedingly well, and separate determinations of it with three separate thermoelectric systems gave identical values within the limits of error of observation. Our confidence that the extrapolation for these 375° is reasonably correct would therefore appear to be justified. Until the gas scale can be extended over this range, the melting point of pure anorthite (1532°) determined in this way will serve as a useful point in thermometry.

$Ab_1An_5$.—This feldspar decidedly resembles anorthite in its relatively low viscosity, the readiness with which it crystallizes, the well marked break in the heating curve at the melting point, and in its tendency to form comparatively large crystals. In general we may say that all these characteristics are somewhat less marked than in anorthite. Our determinations of the melting temperature follow:

$Ab_1An_5$

First Preparation.

| Date. | Element. | Electromotive Force in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Dec. 9, 1903 | A | 15501 | 1504° | slow heating. |
| " 11, " | A | 15363 | 1493 | rapid " |
| " 11, " | No. 3 | 15507 | 1498 | " " |
| " 12, " | 3 | 15599 | 1505 | " " |
| " " " | 3 | 15594 | 1505 | " " |
| " " " | 3 | 15604 | 1506 | slow " |
| " " " | A | 15518 | 1505 | " " |
| | | Mean | 1502° | |

Second Preparation.

| Date. | Element. | Electromotive Force in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Apr. 9, 1904 | No. 3 | 15520 | 1499 | slow heating. |
| " " " | 2 | 15637 | 1497 | " " |

Mean 1498°.

Melting temperature 1500°.

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* Day and Allen, loc. cit.

In one instance, while cooling the molten mass at a rapid rate, we obtained a result which has a most important bearing on the relation of the feldspars to one another, which will be referred to again in the concluding discussion of the experimental data. When the charge had cooled, it was found to consist of a compact mass of rather large crystals, radial in structure, at the bottom of the crucible (fig. 6), and a beautiful, transparent glass above. It was easy to separate the crystalline portion from the glass and to analyze the two separately. The composition of the two portions is practically identical, save for a slightly higher percentage of iron in the crystals.* In harmony with this latter circumstance the color of the crystals was a decided amethyst brown, while the glass was but slightly tinted. The analyses follow:

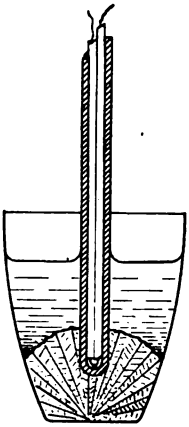
FIG. 6.

**$AB_1AN_5$**

| | Glass Residue Found. | Crystalline Cake Found. |
|---|---|---|
| $SiO_2$ ............ | 47·46 | 47·34 |
| $Al_2O_3$ ............ | 33·56 | 33·51 |
| $Fe_2O_3$ .......... | ·29 | ·47 |
| CaO ............ | 16·99 | 16·84 |
| $Na_2O$ .......... | 1·87 | 1·89 |
| | 100·17 | 100·05 |

It is at once clear from these determinations that the solid phase has the same composition as the liquid phase, so far as it is within the power of chemical analysis to establish it.

$Ab_1An_2$.—In this feldspar we observe the same characteristics as in the two preceding, but they are still less sharply marked. The viscosity is greater, both solidification and melting take place more slowly, and the undercooling is so persistent that the furnace must be cooled slowly or the charge will come out wholly or partly vitreous.

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* A small quantity of iron was contained in the quartz used in preparing the feldspars.

$AB_1AN_2$.

First Preparation.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Oct. 16, 1903 | A | 14895 | 1459° | rapid heating. |
| “ “ “ | No. 3 | 15142 | 1460 | slow “ |
| “ 21 “ | 3 | 15101 | 1457 | rapid “ |
| “ “ “ | 3 | 15220 | 1466 | extremely slow heating. |
| “ 22 “ | 3 | 15204 | 1465 | rapid heating. |
| “ “ “ | 3 | 15160 | 1462 | |
| Dec. 15 “ | 3 | 15116 | 1467 | powdered charge, open crucible. |
| “ “ “ | 3 | 15103 | 1466 | ditto, slower. |
| “ 16 “ | 3 | 15109 | 1467 | solid cake, covered. |
| “ “ “ | 3 | 15044 | 1462 | very fast. |
| “ “ “ | 3 | 15040 | 1462 | same slower. |
| “ “ “ | A | 15035 | 1467 | |
| | | Mean | 1463° | |

Second Preparation.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Feb. 19, 1904 | A | 14945 | 1460° | covered, slow. |
| “ 20 “ | No. 3 | 15096 | 1466 | ditto, faster. |
| “ 25 “ | 2 | 15239 | 1467 | fast. |
| | | Mean | 1464° | |

Melting temperature 1463°.

Here again we made an attempt to discover a possible difference in composition in the first portions to crystallize out of the melt, this time by optical means. We first cooled the charge so rapidly that only a relatively small portion crystallized out in fine, reddish-brown spherulites at the surface and near the wall of the crucible. Without disturbing these, the crucible was then replaced in the furnace and slowly reheated until (about 5 hours) the remaining vitreous material had also become completely crystallized. Upon removing from the furnace, the charge presented a singular appearance. The reddish-brown stars remained undisturbed, while the later crystals were perfectly white. But though so different in appearance, the microscopic examination of slides cut from the different portions showed the two to be optically identical.

We have here another instance of the tendency of the iron to concentrate in the crystals which first form, a tendency which was frequently noticed throughout our work. It also appeared to matter little whether the first crystals formed at the surface or at the bottom of the charge. It is possible that this phenomenon may have significance in ore deposition, but we have not thus far been able to give it adequate attention.

*$Ab_1An_1$*.—With this member of the feldspar group a difficulty in effecting crystallization in the molten mass becomes noticeable. Undercooling will continue until the vitreous melt becomes rigid, unless the cooling is slow or some special effort in the way of mechanical disturbance or the introduction of nuclei is applied. Furthermore, when once precipitated, crystal formation goes on slowly, even when the charge is finely powdered, and the crystals are always small. Of the feldspars at least it is possible to say that the size of individual crystals varied chiefly with the viscosity; the thinner, calcic feldspars always gave large individuals, while $Ab_1An_1$, $Ab_2An_1$, $Ab_3An_1$ and $Ab_4An_1$ crystallized in closely interwoven, increasingly smaller fibers, which gave much difficulty in microscopic study. In comparison with this apparent effect of the viscosity, the rate of cooling was altogether insignificant in determining the size of individual crystals.

Several days were required to complete the crystallization of 100 grams of $Ab_1An_1$ under the most favorable conditions which we were able to bring to bear upon it. The melting temperature of the crystalline feldspar was still fairly well marked, however, and crystallization began in the powdered vitreous material as low as 700°. The melting point of this feldspar is:

$AB_1AN_1$.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Feb. 9, 1904 | A | 14402 | 1416° | covered charge, heating rapid. |
| " 9, | " A | 14400 | 1416 | |
| " 10, | " No. 3 | 14529 | 1421 | very rapid. |
| " 12, | " 2 | 14572 | 1415 | |
| " 27, | " 2 | 14709 | 1426 | very small charge. |
| | | Mean | 1419° | |

Melting temperature 1419°.

*$Ab_2An_1$*.—To effect the complete crystallization of this substance, it is best to reduce it to a fine powder and heat very slowly, holding the temperature for many days at 100–200° below the melting point. When thoroughly crystallized, it has a melting temperature which is determinable with reasonable certainty, but neither this nor any of its thermal phenomena approach the more calcic feldspars in sharpness. For this reason a considerably greater variation will be noticed in the melting points tabulated below.

$AB_2AN_1$.

| Date. | Element. | E. M. F. in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| | | First Preparation. | | |
| Dec. 10, 1903 | A | 13726 | 1362° | |
| " 15, " | A | 13887 | 1374 | |
| " 16, " | A | 13969 | 1381 | very rapid heating. |
| " 16, " | A | 13728 | 1362 | poor. |
| Jan. 18, 1904 | No. 3 | 13967 | 1376 | covered. |
| Feb. 29, " | 3 | 13812 | 1363 | " |
| " 29, " | 3 | 13854 | 1366 | " |
| | | Mean | 1369° | |
| | | Second Preparation. | | |
| Feb. 5, 1904 | No. 2 | 13990 | 1369° | covered. |
| | | Third Preparation. | | |
| Mch. 25, 1904 | 3 | 13752 | 1358 | |
| " 29, " | 2 | 13995 | 1370 | |
| Apr. 5, " | 3 | 13756 | 1358 | |
| | | Mean | 1362° | |

Melting temperature 1367°.

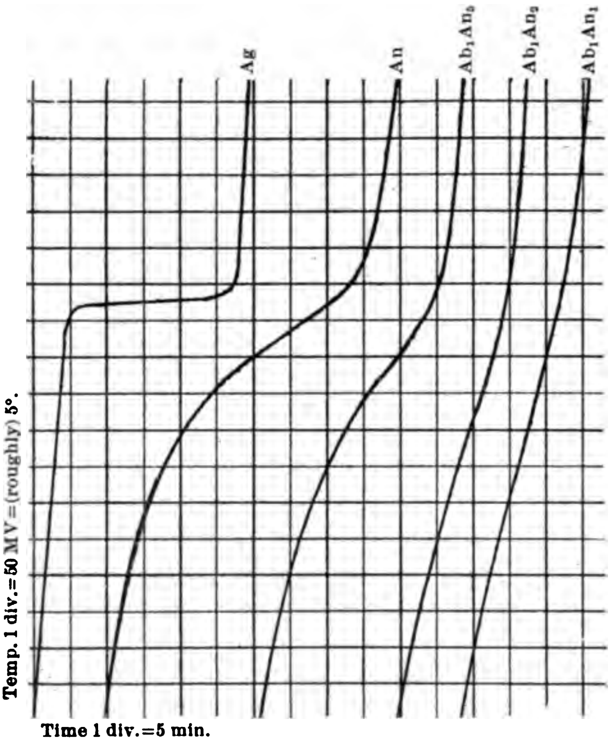

FIG. 7.

From here on to the albite end of the series, viscosity becomes very troublesome in restraining crystallization. The breaks which mark the melting temperature on the heating curve of $Ab_3 An_1$ are so slight as to make the determination difficult and somewhat uncertain. It is not that temperature measurement is less accurate here than elsewhere, for these temperatures are more accessible than the melting point of anorthite, to which reference has been made in this connection. These ultra-viscous materials do not melt at a constant temperature but over a considerable range of temperature, as we shall undertake to show in some detail, with illustrations from photographs, in the discussion of albite. A glance at a series of curves (fig. 7) plotted from our observations upon metallic silver and the feldspars An, $Ab_1An_8$, $Ab_1An_2$ and $Ab_1An_1$ in such a way as to bring their melting points together, will show clearly the nature of this difficulty. The melting point of the metal is sharp, but with anorthite a change in the character of the phenomenon is noticeable. Its poor conductivity for heat and its viscosity, which, though small compared with the other feldspars, is very great compared with silver, have rounded off the corners until a really constant temperature for a period of a minute or more during the melting is nowhere to be found. The nearest approach to a melting *point* is where the rise in temperature is slowest, and this will occur when the portion nearest to the thermoelement (see fig. 1) melts. A series of melting point curves containing a typical one for each of the observed feldspars, is reproduced here exactly as observed (see page 114). The numbers represent the electromotive force of the thermoelements at intervals of one minute, together with a column of differences at the right of each record. The E.M.F. will be seen to approach a minimum as melting progresses and to increase again when it is complete. This minimum rise in the temperature of course indicates the maximum absorption of heat. For purposes of rough orientation 10 MV may be considered equivalent to one degree.

There is no circulation in these viscous melts and nothing to assist in distributing the heat uniformly. The melting point is therefore not marked by a constant temperature but by the point of greatest inclination of the tangent to the curve, with a limit of error which increases with increasing viscosity. With $Ab_3An_1$ it was barely discernible and with $Ab_4An_1$ all trace of the heat of fusion was lost.* Slow heating or rapid

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* Only a small portion of the charge could be crystallized. The relatively small heat of fusion of the crystallized portion was therefore superposed upon the larger specific heat of the glass. This, together with the effect of the viscosity, destroyed all record of the melting.

### TIME CURVES

(in Microvolts as observed).

| An MV | An ΔV | Ab$_1$An$_8$ MV | Ab$_1$An$_8$ ΔV | Ab$_1$An$_2$ MV | Ab$_1$An$_2$ ΔV | Ab$_1$An$_1$ MV | Ab$_1$An$_1$ ΔV | Ab$_2$An$_1$ MV | Ab$_2$An$_1$ ΔV | Ab$_3$An$_1$ MV | Ab$_3$An$_1$ Δ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15050 | 156 | 13530 | 300 | 11700 | 510 | 13400 | 89 | 12480 | 53 | 12754 | 39 |
| 15206 | 135 | 13830 | 300 | 12210 | 445 | 13489 | 84 | 12533 | 57 | 12793 | 41 |
| 15341 | 100 | 14130 | 240 | 12655 | 305 | 13573 | 74 | 12590 | 58 | 12834 | 43 |
| 15441 | 85 | 14370 | 190 | 12960 | 276 | 13647 | 68 | 12648 | 53 | 12877 | 39 |
| 15526 | 68 | 14560 | 153 | 13236 | 205 | 13715 | 63 | 12701 | 51 | 12916 | 38 |
| 15594 | 56 | 14713 | 125 | 13441 | 154 | 13778 | 58 | 12752 | 45 | 12954 | 35 |
| 15650 | 47 | 14838 | 104 | 13595 | 127 | 13836 | 55 | 12797 | 43 | 12989 | 33 |
| 15697 | 41 | 14942 | 86 | 13722 | 110 | 13891 | 51 | 12840 | 41 | 13022 | 31 |
| 15738 | 35 | 15028 | 73 | 13832 | 100 | 13942 | 49 | 12881 | 36 | 13053 | 29 |
| 15773 | 29 | 15101 | 63 | 13932 | 90 | 13991 | 47 | 12917 | 35 | 13082 | 27 |
| 15802 | 27 | 15164 | 54 | 14022 | 85 | 14038 | 45 | 12952 | 35 | 13109 | 25 |
| 15829 | 24 | 15218 | 46 | 14107 | 79 | 14083 | 42 | 12987 | 33 | 13134 | 26 |
| 15853 | 22 | 15264 | 39 | 14186 | 70 | 14125 | 41 | 13020 | 33 | 13160 | 24 |
| 15875 | 16 | 15303 | 36 | 14256 | 67 | 14166 | 40 | 13053 | 35 | 13184 | 23 |
| 15891 | 15 | 15339 | 32 | 14323 | 70 | 14206 | 39 | 13088 | 33 | 13207 | 22 |
| 15906 | 14 | 15371 | 27 | 14393 | 63 | 14245 | 39 | 13121 | 33 | 13229 | 21 |
| 15920 | 13 | 15398 | 25 | 14456 | 58 | 14284 | 39 | 13154 | 30 | 13250 | 20 |
| 15933 | 12 | 15423 | 24 | 14514 | 57 | 14323 | 40 | 13184 | 31 | 13270 | 18 |
| 15945 | 11 | 15447 | 21 | 14571 | 49 | 14363 | 39 | 13215 | 33 | 13288 | 18 |
| 15956 | 9 | 15468 | 20 | 14620 | 50 | 14402 | 42 | 13248 | 35 | 13306 | 15 |
| 15965 | 9 | 15488 | 16 | 14670 | 44 | 14444 | 44 | 13283 | 35 | 13321 | 16 |
| 15974 | 9 | 15504 | 17 | 14714 | 45 | 14488 | 50 | 13318 | 37 | 13337 | 17 |
| 15983 | 9 | 15521 | 16 | 14759 | 38 | 14538 | 67 | 13355 | 33 | 13354 | 19 |
| 15992 | 6 | 15537 | 15 | 14797 | 42 | 14605 | 71 | 13388 | 33 | 13373 | 20 |
| 15998 | 6 | 15552 | 15 | 14839 | 38 | 14676 | | 13421 | 30 | 13393 | 22 |
| 16004 | 8 | 15567 | 14 | 14877 | 35 | | | 13451 | 32 | 13415 | 24 |
| 16012 | 8 | 15581 | 13 | 14912 | 35 | | | 13483 | 33 | 13439 | 27 |
| 16020 | 8 | 15594 | 14 | 14947 | 35 | | | 13516 | 31 | 13466 | 27 |
| 16028 | 5 | 15608 | 14 | 14982 | 31 | | | 13547 | 29 | 13493 | 27 |
| 16033 | 7 | 15622 | 15 | 15013 | 33 | | | 13576 | 26 | 13520 | 28 |
| 16040 | 8 | 15637 | 17 | 15046 | 36 | | | 13602 | 25 | 13548 | 28 |
| 16048 | 8 | 15654 | 18 | 15082 | 36 | | | 13627 | 21 | 13576 | |
| 16056 | 8 | 15672 | 23 | 15118 | 42 | | | 13648 | 18 | | |
| 16064 | 7 | 15695 | 38 | 15160 | 51 | | | 13664 | 11 | | |
| 16071 | 7 | 15733 | 63 | 15211 | 95 | | | 13675 | 21 | | |
| 16078 | 9 | 15796 | | 15306 | 113 | | | 13696 | 28 | | |
| 16087 | 12 | | | 15419 | | | | 13724 | 34 | | |
| 16099 | 11 | | | | | | | 13758 | 36 | | |
| 16110 | 12 | | | | | | | 13794 | 39 | | |
| 16122 | 12 | | | | | | | 13833 | 40 | | |
| 16134 | 15 | | | | | | | 13873 | 41 | | |
| 16149 | 14 | | | | | | | 13914 | 40 | | |
| 16163 | 18 | | | | | | | 13954 | 44 | | |
| 16181 | 16 | | | | | | | 13998 | 52 | | |
| 16197 | 16 | | | | | | | 14050 | | | |
| 16213 | 19 | | | | | | | | | | |
| *16232* | | | | | | | | | | | |

heating merely acts to change the general inclination of the curve but not to emphasize the absorption of heat.

By way of conveying a concrete impression, it may be added that $Ab_3An_1$ just above its melting temperature resists the introduction of a stout platinum wire (1·5$^{mm}$ diameter) unless the cold wire is thrust in very quickly and vigorously. If the wire is first allowed to become hot in the furnace, it will give way itself instead. No acceleration of the melting process tending to sharpen the break in the curve appears to be possible without the introduction of new substances or new conditions (water vapor under pressure for example) which would take the experiment outside the definition of a "dry melt." We have undertaken some preliminary experiments in these directions, but they belong to another phase of the subject.

A number of efforts were made to locate the melting temperature of $Ab_3An_1$, which are given in the list below. Although two days were required to crystallize each charge of the material sufficiently for a determination, the recorded numbers possess but little significance, as will be clear from the foregoing.

$AB_3AN_1$

First Preparation.

| Date. | Element. | Electromotive Force in MV. | Temperature. | Remarks. |
|---|---|---|---|---|
| Nov. 23, 1903 | A | ..... | 1325° | |
| " 25, " | A | 13415 | 1336 | |
| " 28, " | A | 13698 | 1359 | |
| Dec. 26, " | A | 13319 | 1328 | |
| Jan. 14, 1904 | No. 3 | 13893 | 1370 | |
| | | Mean | 1344° | |
| | | Second Preparation. | | |
| Mch. 11, 1904 | A | 13218 | 1320 | |
| " 14, " | No. 3 | 13469 | 1335 | |
| | | | 1329° | |

Approximate melting temperature 1340°.

*$Ab_4An_1$*.—With $Ab_4An_1$ a third proof of the identity of composition of the first crystals to separate and the vitreous residue was obtained. The optical identification of this feldspar is absolute. If we could obtain crystals at all in a melt of this chemical composition, therefore, it would offer a crucial test of the relation of the solid and liquid phases in a part of the curve where no melting point or specific gravity determination upon crystals was possible. After some days of nearly continuous heating at a temperature somewhat below its assumed melting point, a few crystals of $Ab_4An_1$ were obtained and identified.

*Albite.*—From the experiments upon natural albite and orthoclase, which have been described, and after observing the effect of the increasing viscosity as we approached the albite end of the artificial plagioclase series, we had no expectation of finding a melting point for either in the ordinary sense. Nor did we in fact succeed in locating a point of any real significance in this connection. The various trials which were made were simply calculated to throw all the light possible upon the character of the change from (crystalline) solid to liquid in such extremely viscous substances. The return change or recrystallization of such substances from the melt (solidifying point) without the introduction of modifying conditions has never been accomplished. The time required to do it is certainly very great, probably much greater than the demonstration is worth at the present stage of experimentation in this field.

Crystalline albite has been produced under exceptional conditions several times—by Hautefeuille,* by heating a very alkaline alumino-silicate with sodium tungstate for 30 days at 900°-1000°; by Friedel and Sarasin,† using an atmosphere of water-vapor under high pressure and a moderately high temperature (an aqueo-igneous fusion); by J. Lenarčič,‡ at ordinary pressure and high temperature by crystallization out of a mixture of melted albite and magnetite (1 part magnetite, 2 parts albite by weight), and by others. It may be noted in passing that, entirely apart from the solution relations, the last mentioned process reduces the viscosity to an entirely different order of magnitude from that of pure albite; magnetite melts to form a thin liquid almost of the consistency of water and even in 1:10 solution with albite forms a fairly mobile liquid. We endeavored to repeat portions of the work of Hautefeuille and Lenarčič, but were obliged to postpone a systematic inquiry into the conditions of crystallization which involved the addition of other components or extraordinary pressures, until our plant could be somewhat extended.

Hautefeuille describes his successful preparation as a "solution" of the alkaline alumino-silicate in sodium tungstate out of which the albite slowly crystallizes after long heating, but he remarks that the crystallization does not take place if the mixture is heated sufficiently to melt the components of the charge into a homogeneous glass. In that case he obtained only a vitreous white enamel. The case does not appear, therefore, to be one of simple solution, out of which the same solid phase always reappears upon reproducing given conditions of temperature and concentration. On the contrary, as Hautefeuille describes the experiment, the components of the albite remain as independent solid phases, which are then assembled in some manner through the intermediary action of the melted tungstate.

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* Hautefeuille, Annales de l'École Normale Supérieure, 2d series, ix, p. 363, 1880.

† Friedel and Sarasin, Bull. Min., clviii, 1879; lxxi, 1881.

‡ J. Lenarčič, Centralblatt f. Min., xxiii, 705, 1903.

Notwithstanding the fact that our interest was confined for the moment to the mere production of a small quantity of chemically pure crystalline albite, we ventured to proceed along the lines of Hautefeuille's unsuccessful trial. We first prepared a chemically pure albite glass, i. e., we melted the components into a homogeneous mass before adding tungstate. This glass was then finely powdered, thoroughly mixed with an excess of powdered sodium tungstate and maintained continuously for 8 days at 1100°. Upon removing from the furnace at the close of the heating, both albite and tungstate were found to have been completely melted and to have separated into two distinct layers according to their specific gravities, the albite glass being above, and showing no trace of crystallization. A second charge was then prepared with only 50 per cent of the tungstate, powdered and mechanically mixed as before, and maintained at a temperature of 900° for 17 days. This time we were successful. After the sodium tungstate had been dissolved away with water, the albite appeared as a powder of about the fineness to which it had originally been pulverized, except that the fragments were now crystalline and apparently homogeneous albite. In thin section, under the microscope, to our considerable surprise, it appeared that the original glass fragments were unchanged in form. The bounding surfaces were all conchoidal fractures, as they came from the hammer, and evidently had not been in solution with the tungstate at all. Its optical properties showed it to be undoubted albite and the specific gravity was 2·620.

The preparation of albite which we had synthesized by heating with an equal weight of sodium tungstate was first purified by thorough washing with warm water, but this was not sufficient to remove all the tungstate. A determination of tungstic acid showed 0·62 per cent still present, which is equivalent to 0·78 per cent of sodium tungstate. After removing the water by heating carefully to a dull redness, the product was submitted to a microscopic examination, which showed it to be entirely crystalline and apparently homogeneous. Determinations of the specific gravity gave 2·620 (see table, p. 128). If this is corrected for 0·78 per cent of sodium tungstate of specific gravity 4·2, we obtain 2·607.

A portion of this preparation was then purified further by fusing for a few minutes with acid sodium sulphate (Hautefeuille) at as low a temperature as practicable, after which the excess of sulphate was extracted with water and the product dried (the temperature was raised to a dull red heat to remove all water) and analyzed.

| | Found. | Calculated. |
|---|---|---|
| $SiO_2$ | 68·74 | 68·68 |
| $Al_2O_3$ and $Fe_2O_3$ | 19·56 | 19·49 |
| $Na_2O$ | 11·73 | 11·83 |
| $SO_3$ | ·02 | |
| $WO_3$ | ·16 | |
| | 100·21 | |

The specific gravity of it was 2·604, which may be corrected as before for the remaining trace of tungstic acid assumed to be in the form of the sodium salt. The value then falls to 2·601.

A second portion of the same albite was purified by another process. Instead of fusing with acid sodium sulphate, the powdered sample was first digested for a short time with dilute hydrochloric acid (1:1), which set free tungstic acid. The excess of hydrochloric acid was removed with water, the tungstic acid with ammonia, and finally the excess of reagent and the ammonium tungstate by further washing with water. When dried at a low red heat, the preparation had the following composition:

| | Found. | | Calculated. |
|---|---|---|---|
| $SiO_2$ | 68·91 | | 68·68 |
| $Al_2O_3$ | 18·95 | 19·13 | 19·49 |
| $Fe_2O_3$ | ·18 | | |
| $Na_2O$ | 11·59 | | 11·83 |
| $WO_3$ | ·22 | | |
| $H_2O$ | ·13 | | |
| | 99·98 | | |

The specific gravity determination gave 2·615, which when corrected for a small amount of sodium tungstate becomes 2·612. If, as is possible after the above treatment, the tungstic acid is present as the anhydride, sp. gr. 7·1, the correction would lower the value to 2·605, in excellent agreement with the other determinations.

The products of both methods of purification were carefully scrutinized by the microscope, but no conclusion could be reached as to which was the purer. Neither the sodium sulphate fusion nor the digestion with acid and ammonia appeared to have changed the particles in the slightest degree. Diligent search was made for opaque or amorphous matter on the surface of the grains, or any other indication of decomposition, but none was found. While the chemical analysis indicates a rather higher purity for the first product, purified by fusion, the differences are nearly within the limits of error and therefore hardly conclusive. Both powders were ground finer than usual for the specific gravity determinations to avoid errors introduced by a spongy structure.

Reverting now to Hautefeuille's directions, it is clear that glass of albite composition crystallizes homogeneously under substantially the conditions which he obtained, as well or better than the mechanically mixed component parts; but the part played by the tungstate requires some further experimental study before a conclusion can be reached.

Except for the specific gravity, the experiments upon crystalline albite and orthoclase which follow were made upon natural specimens from well-known localities (a fragment of the Mitchell Co. albite is shown in Plate I, 1), for which we are indebted to Dr. G. P. Merrill of the National Museum and Dr. Joseph Hyde Pratt, State Mineralogist of North Carolina. The specimens were selected with great care, but like all natural specimens, they contained other feldspars and inclusions. The analyses follow:

| | Albite. (Amelia Co., Va.-Nat. Mus.) Found. | Albite. Calculated, Anhydrous. | Albite. (Mitchell Co., N. C.-Pratt.) Found. | Albite. Calculated, Anhydrous. | Microcline. (Mitchell Co., N. C.-Nat. Mus.) Found. | Microcline. Calculated, Anhydrous. |
|---|---|---|---|---|---|---|
| $SiO_2$ | 68·22 | 68·71 | 66·03 | 66·42 | 65·49 | 65·83 |
| $Al_2O_3$ | 19·06 | 19·20 | 20·91 | 21·03 | 17·98 | 18·07 |
| $Fe_2O_3$ | ·15 | ·15 | ·18 | ·18 | ·36 | ·36 |
| CaO | ·40 | ·40 | 2·00 | 2·00 | ·42 | ·42 |
| $Na_2O$ | 11·47 | 11·53 | 9·97 | 10·03 | 2·29 | 2·30 |
| $K_2O$ | ·20 | ·20 | ·70 | ·70 | 12·95 | 13·02 |
| $H_2O$ | ·69 | .... | ·59 | .... | ·51 | .... |
| | 100·19 | | 100·38 | | 100·00 | |

It will be remembered that in the preliminary experiments (p. 98) the heating curve of these natural feldspars did not show an absorption of heat which we were able to detect; our first step was therefore to find out what manner of process it was by which a charge of crystalline albite or orthoclase became amorphous without leaving a thermal record behind.

We prepared a charge of albite glass from a previous melt powdered to "100-mesh." In this glass powder a small crystal fragment (perhaps 2 x 5 x 10$^{mm}$), from the same original specimen and therefore of the same chemical composition, was imbedded beside the thermoelement as indicated in fig. 8. This charge was heated slowly to exactly 1200°, slowly cooled again and several thin sections prepared from the crystal fragment and its immediate neighborhood. What the microscope showed can best be seen from the accompanying illustrations (Plate I, 2 et seq.),—groups of crystal fragments of microscopic size, preserving their original orientation (extinction) perfectly but with narrow lanes of glass where cleavage and other cracks had been, forming a perfect network without a trace of disarrangement. Considerable melting had taken place but no flow. Neither had the charge as a whole made any movement to take the form of the containing vessel after sintering together (fig. 9).

Surmising that we had accidentally hit upon the approximate melting temperature, a fresh charge of like material was

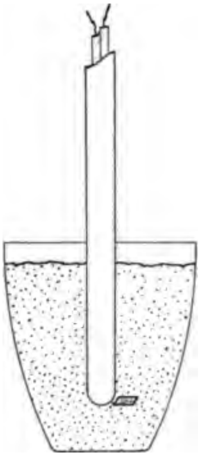


Fig. 8.

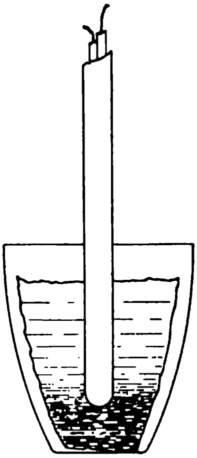
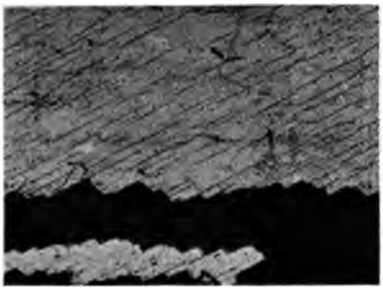


Fig. 9.

prepared, and the same experiment carefully repeated except that the temperature was carried up to 1206° and maintained there for 30 minutes. Instead of showing the melting to be complete, the slides (Plate I, 3) looked precisely like the first save that the lanes of glass were somewhat wider and the crystal fragments relatively smaller than before. Further trials under precisely the same conditions with the temperature increased to 1225° (Plate I, 4) and 1250° (Plate I, 5) respectively, for like periods of time, showed only more advanced stages in the same process. In the latter case the

1



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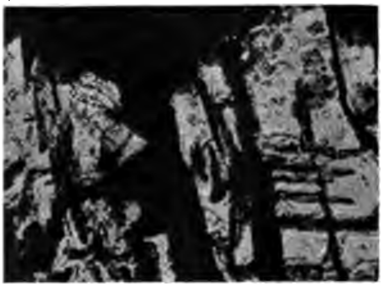

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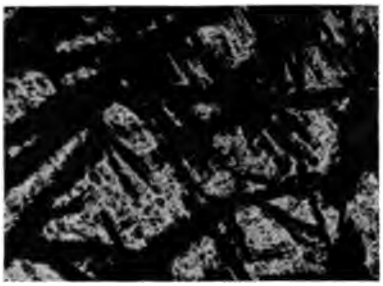

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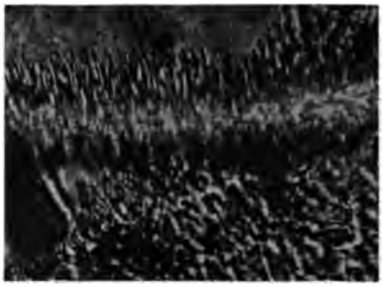

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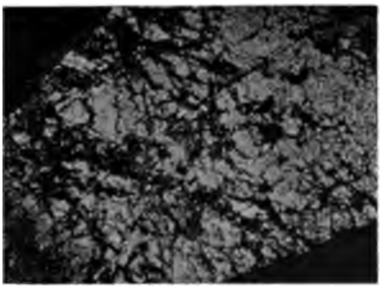

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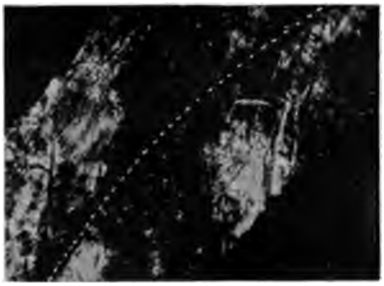

1. Original Albite (Mitchell Co.), ×10. 2. Fragment of same heated to 1200°, ×20. 3. Another fragment, 1206°, ×20. 4. Another, 1225°, ×20. 5. Another, 1250°, ×20. 6. Another (×300) four hours at 1125°. 7. Another, bent at 1200°, ×10. 8. Microcline bent at *1200°*, ×10; note the direction of cleavage (cf. dotted line). *All the photographs were made through crossed nicols, vitreous areas are therefore black.*

remaining crystal fragments were relatively very small compared with the separating lanes of glass, but the orientation of the tiny particles still remained perfectly undisturbed.

The evidence contained in this series of slides shows plainly that we have here an unfamiliar condition—a case of a crystalline compound persisting for a long time above its melting temperature for a given pressure. Albite or orthoclase glass sinters tightly at 800°. At the temperature when melting began, therefore (below 1200°), the charge consisted of crystal fragments of microscopic size imbedded in a large vitreous mass of the same composition and known temperature. These fragments melted so slowly over the 50° included between the first slide (Plate I, 2) and the last (Plate I, 5), with the rate of heating slow (1° in 2 min.), and the upper temperature continued for 30 minutes, as to leave considerable portions unmelted at the close. Furthermore the extreme viscosity, of which further evidence will be given directly, and the absence of any disturbance in the orientation of the particles indicating flow, assured us that the lanes of glass represented actual melting and not an inflow of glass from without. Finally, the perfectly homogeneous character of the glass and the unchanged appearance of the crystals as heating progressed, gave no hint of any chemical decomposition.

In the hope of obtaining a point of value for comparison with the melting points of the other feldspars, some time and patience were expended in trying to locate the lowest temperature at which certain evidence of melting appeared. We did not extend any single trial beyond a single day, so that our results can not pretend to establish the lowest point at which albite melts. Such an effort with a natural specimen known to contain impurities would yield nothing of value. Mitchell County albite showed signs of melting after four hours at 1100°. Under a high power the crystal edges appeared weathered or toothed—strongly resembling the incipient melting of the ice on a frosted window pane. These extremely fine teeth could be followed through the slide on exposed edges. At 1125° (Plate I, 6, ×300) a four-hours heating gave unmistakable glass in tiny pockets and lanes.

The above experiments with the Cloudland albite were completed before we obtained the Amelia County material, but the latter proved to be so much nearer to the type of pure soda feldspar that nearly all the experiments were repeated with it except that the crystal blocks were imbedded in powdered crystals. We did not develop any new fact, however; the effects noted above reappeared in the same order except perhaps that melting went on a little faster in the Amelia County specimen. As much melting was found after one-half hour at

1200° with the Amelia County sample as the Cloudland (Mitchell County) showed in the same time at 1225°, which is readily enough explained by the relatively large quantity of lime (anorthite) in the latter.

Since both time and temperature enter into the delimitation of the metastable region, further trials at temperatures above 1250° did not seem likely to add anything to the knowledge already obtained. And if the heating were very rapid, the temperature differences within the charge would be considerable. A few isolated crystalline fragments were found in an orthoclase melt which had been heated as high as 1400° for another purpose. Another which had reached nearly 1500° showed no orthoclase, but one or two minute quartz inclusions still remained undissolved.

We made a rough attempt to get a more tangible idea of the viscosity of these feldspars at their melting temperature in the following way. A long, slender sliver (perhaps $30 \times 2 \times 1^{mm}$) of albite and one of microcline were chipped from larger portions, spanned across small empty platinum crucibles, and placed side by side in the furnace. These exposed crystals were heated to 1225° for three hours. When removed, they were completely amorphous (melted) but retained their position with hardly a trace of sagging.

After this a number of similar slivers were prepared, mounted in the same way, and heated to temperatures of from 1200° to 1300° for a few moments. At their highest temperature a platinum rod was inserted through a hole in the top of the furnace and allowed to rest as a load upon the middle of the crystal bridges. Under this load the partially melted slivers gradually gave way, and were taken from the furnace in the various forms shown in the illustrations. Slides cut from these showed no squeezing out of the melted portion between the crystal fragments on the side toward the center of curvature, or open cracks on the outer side (Plate I, 7, 8.) On the other hand, a variable extinction angle in an unbroken crystal fragment frequently gave unmistakable evidence of the bending of the crystal as well as the vitreous portion. From these qualitative experiments it seems possible to assert with confidence that the order of magnitude of the viscosity of the molten portion (glass) is the same as the rigidity of the crystals at these temperatures.

Plate I, 7, shows a piece of Mitchell Co. albite heated to 1200° under load. The sagging is indicated by the curved cleavage cracks. Plate I, 8, shows a sliver of microcline which has been heated to 1200° under load. The sagging is shown by the curvature of the crystal edges and the cleavage cracks.

The black portions are glass. It is interesting to observe that while the crystal has melted completely across, there has been no displacement of the cleavage plane.

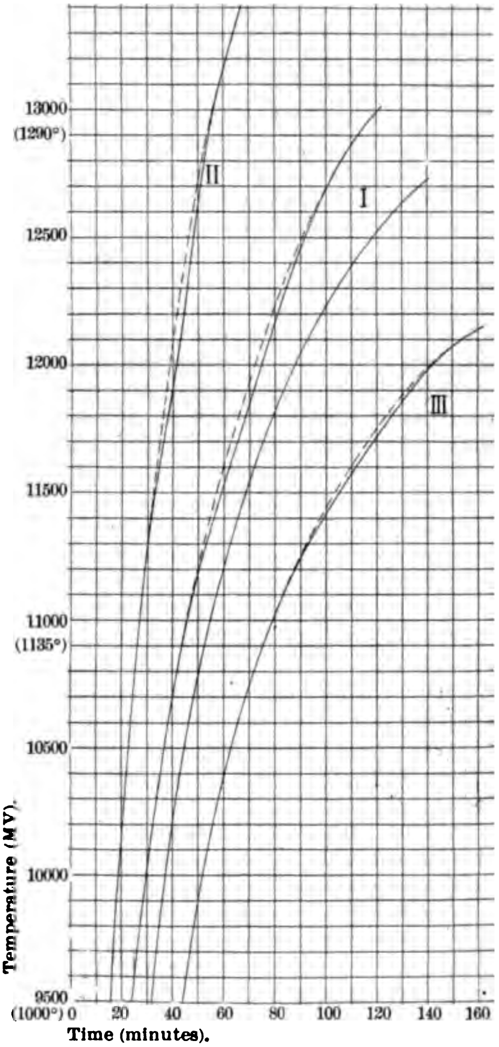

FIG. 10.

The preceding experiments gave a clear idea of the phenomena attending the melting of albite and orthoclase, and convinced us that the absorption of heat accompanying fusion, which we had searched for in vain upon the heating curves in the earlier experiments, had eluded us merely because it was extended over so long a stretch of the curve as not to be noticeable. Some very exact measurements of the temperature change from minute to minute were therefore made in the hope that a more intelligent search might be more successful. Separate charges of glass and of crystals of the same composition and of equal weight were prepared and successively heated in the same furnace with the same current. The specific heat is of course not identical in the two cases, but the curves were comparable in form. Above 1100° we felt sure that one of the curves must contain an absorption of heat which would be absent from the other. Such a pair of curves, I, taken from the microcline measurements, is reproduced in the adjoining figure (fig. 10), and appears to show such an absorption clearly, extending from 1135° to 1275°. The dotted line shows the course of the curve without the absorption, as inferred from the glass curve. The same figure contains two other curves (II, III), similarly treated, which were made upon fresh charges of the same material, but with different rates of heating. It will be noticed that the absorption begins to be noticeable at a slightly lower temperature if the heating is slower.

This peculiar behavior shown by compounds which melt to form hyperviscous liquids seems not to have been observed before and to contain features of more than ordinary interest. Here are evidently crystalline substances which not only can exist for considerable periods of time at temperatures far above their melting temperatures, but which melt with extreme slowness in the lower portion of this range of instability. It would certainly be no exaggeration to say that the albite with which we worked would require some weeks to reach the amorphous state if maintained at a constant temperature of 1125°.

An interesting question arises here as to the state of the crystalline material at temperatures above its melting point. It is easily conceivable that the crystals are merely superheated without loss of any of their properties as solids, and that they thus present an analogy to superheated liquids. In the transformation (Umwandlung) of a solid crystalline substance into another crystal form, such superheating has long been known. The change is dependent upon temperature and pressure like ordinary fusion, but it is possible to pass the transformation temperature in either direction. This must be due to the unfavorable opportunity for molecular motion which solids afford, and the latter should differ in no essential particular from ultraviscosity.

On the other hand, it does not seem a violation of any known principle to conceive cases of unstable equilibrium in which the molecules of a liquid are oriented as in a crystal. Maxwell's demons might arrange them much like a school of fish and there is no apparent reason why the fluidity should be destroyed thereby. Were such an arrangement one of minimum potential, the mass would be a liquid crystal. In the supposed case such a substance would possess a melting point dependent upon the temperature and pressure, above which Maxwell's definition* of a true solid—that its viscosity be infinite—would no longer obtain, although deorientation might not become apparent, in the face of extreme viscosity, for a considerable time afterward. Such a melting point would be determinable only with the greatest difficulty, for all the functions—mechanical, thermal or electrical—which usually become suddenly discontinuous at the melting point would be equally powerless to define a change of state in the face of such extreme molecular inertia.

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* Maxwell's Scientific Papers, vol. ii, p. 620.

In substances like these, which are still viscous at the temperature of the electric arc, the sharpness of a minimum due to heat absorption, for example, is not dependent upon the magnitude of that absorption entirely, but also upon the rapidity with which the change which involves it proceeds. In albite and orthoclase, the velocity of this change is very small.

*Specific Gravity.*—The study of the specific gravities yielded one interesting result which was not anticipated. The artificial feldspars, being chemically pure and homogeneous, gave a perfectly definite specific gravity which could be determined with great accuracy if the specimen was completely crystallized. If vitreous inclusions were still present, the results were of course variable and were all too low. It was anticipated that the density of pure glasses, transparent and free from bubbles, as they were in the more calcic members of the series, might yield values varying more or less with the rate of cooling, or after annealing, but this did not prove to be the case. Our results did not vary more than two units in the third decimal place in the same preparation even with the more calcic feldspars which required to be very rapidly chilled in order to cool the melt without crystallization.

The determination of specific gravities is a trite subject, but we have found the common methods liable to such grave errors that we venture to give some useful details. The error due to the evaporation of water about the stopper of the pycnometer is very much less with finely ground stoppers than with coarse grinding, and if the stopper is slightly vaselined just before the final weighing, the error from this cause will hardly affect the third decimal place with $25^{cc}$ pycnometers. The simplest form of flask with a small capillary opening in the stopper, is, in our judgment, far superior to one carrying a thermometer. The temperature should be made sure by the use of the thermostat.

For removing the air from a powdered charge, we used the device of G. E. Moore,* slightly modified, as indicated in the accompanying sketch. The bulb *A* contains boiled water.

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* G. E. Moore, Jour. prakt. Chem., ii, p. 319, 1870.

When the apparatus is exhausted, the water is allowed to flow back into the pycnometer containing the charge ; then by tapping and warming with water at 40–50° to produce boiling within, the air is effectively removed. The material projected from the flask, if the boiling is violent, is then washed back from the tube *B* with boiled water and any small particles remaining are washed into a tared dish and finally weighed. It is very important that not the smallest grain of material should get into the ground joint between the neck and stopper of the pycnometer. To obviate this, wipe out the neck with filter paper before stoppering and burn it in the tared dish.

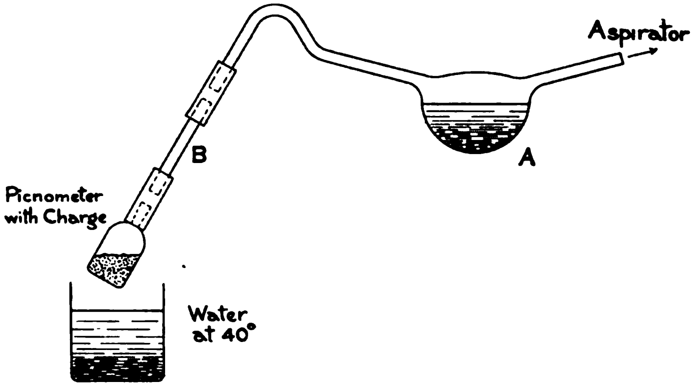

FIG. 11.

If the powder is very fine it is advisable to allow the filled pycnometer to stand for some hours in the thermostat, in order that suspended material may settle. With a $25^{cc}$ pycnometer and 5 to 10 grams of material, this method usually yields concordant results to the third decimal place, and the error from all causes should never be greater than two units (± 1) in the third place. A determination of this accuracy is of course subject to a correction for buoyancy, and all the numbers which follow have been thus corrected.

There is another error to which accurate specific gravity determinations upon powdered minerals will be subject unless suitable precaution is taken. The exposure to the air during the period of grinding the samples gives opportunity for the condensation of sufficient atmospheric moisture upon the grains to affect the weight in air. The amount varies measurably with the size of the grains, as will be seen from the accompanying data, and probably with the degree of saturation of the atmosphere and the time of exposure.

DETERMINATION OF MOISTURE IN 1 GR. OF POWDERED MINERAL UPON EXPOSURE TO THE AIR.

| Mineral. | Fineness (mesh). | Moisture. |
|---|---|---|
| Orthoclase (natural glass) | $<150$ | ·0061 gr. |
| $Ab_1An_6$ (artificial glass ) | selected, coarse | ·0000 |
| " ( " cryst. ) | $<100 >120$ | ·0010 |
| $Ab_1An_1$ ( " glass ) | $<100 >120$ | ·0007 |
| " ( " cryst. ) | $<100 >120$ | ·0010 |
| Ab (natural " ) | coarse | ·0006 |
| Ab ( " " ) | $<150$ | ·0069 |
| | | |
| Orthoclase (natural cryst.) | $<120 >150$ | ·0011 gr. |
| " (same sample ) | $<150$ | ·0031 |
| " ( " " ) | still finer | ·0059 |
| | | |
| Orthoclase (artificial glass) | everything $<100$ | ·0065 gr. |
| " (portion of same) | $>150$ | ·0022 |

$<$ = finer than $>$ = coarser than

In the last two groups, note that the moisture in selected portions of the same sample varies with the fineness.

We also verified the conclusion of Bunsen* that this adsorbed moisture is not removed at temperatures only slightly above 100° but requires 600° to 800°—equivalent to a low red heat. Several samples for which the moisture had been determined were laid away in corked test tubes for a number of weeks, after which redetermination gave exactly the former value.

It is worth noting in this connection that these measured quantities of adsorbed water are of the same order of magnitude as those usually obtained for the water content in feldspar analyses,† where again, of course, the finer the sample is ground for the analysis, the greater the possible error from this cause. It may be that a part and occasionally all of the moisture usually found in these analyses is adsorbed and the significance of its presence there mistaken.

The number of feldspars of which specific gravity determinations could be made was limited only by the possibility of obtaining complete crystallization within a reasonable time. Thus $Ab_2An_1$ was reheated many times before a constant value was reached. $Ab_3An_1$ required 17 days and $Ab_4An_1$ was not completely crystallized in any of our attempts. Crystalline albite was produced under other conditions.

The specific gravities of the glasses and of so many of the crystalline mixtures as we could obtain are tabulated below:

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* Wied. Ann., xxiv, p. 327, 1885.

† Dana, System of Mineralogy, 6th ed., p. 314 et seq.

SPECIFIC GRAVITIES OF ARTIFICIAL CRYSTALLINE FELDSPARS.

| | An | $Ab_1An_5$ | $Ab_1An_2$ | $Ab_1An_1$ | $Ab_2An_1$ | $Ab_3An_1$ | Ab (First Determination) |
|---|---|---|---|---|---|---|---|
| | 2·764<br>2·765 | 2·734<br>2·734 | 2·710<br>2·708 | 2·680<br>2·680 | 2·660<br>2·660<br>2·660 | 2·650<br>2·648 | *c* 2·620<br>2·620 |
| | *a* 2·767 | *a* 2·732<br>2·732 | *b* 2·710<br>2·710 | *b* 2·679<br>2·677 | *b* 2·659<br>2·660 | | *d* 2·614<br>2·615 |
| | | *a* 2·734 | | | | | *e* 2·604 |
| ean | 2·765 | 2·733 | 2·710 | 2·679 | 2·660 | 2·649 | |

SPECIFIC GRAVITIES OF FELDSPAR GLASSES.

| | An | $Ab_1An_5$ | $Ab_1An_2$ | $Ab_1An_1$ | $Ab_2An_1$ | $Ab_3An_1$ | Ab |
|---|---|---|---|---|---|---|---|
| | 2·700<br>2·700 | 2·647<br>2·649 | 2·593<br>2·594 | 2·533<br>2·534 | 2·482<br>2·482 | 2·458<br>2·459 | 2·383<br>2·382 |
| | | 2·648<br>2·647 | 2·591<br>2·591 | | *a* 2·485 | | |
| | | 2·648<br>2·649 | 2·590<br>2·588 | | | | |
| | | 2·647<br>2·647 | | | | | |
| ean | 2·700 | 2·648 | 2·591 | 2·533 | 2·483 | 2·458 | 2·382 |

Determinations in duplicate are enclosed in brackets.

*a.* Another preparation.

*b.* Same material reheated for several days at temperatures about 150° below the melting point.

*c.* Contained about 0·8 per cent of sodium tungstate.

*d.* Purified by warming with dilute hydrochloric acid, then with water, and afterwards with ammonia.

*e.* Purified by fusion with acid sodium sulphate.

*f.* Assuming the residual tungsten to be present as $Na_2WO_4$.

*g.* Assuming the residual tungsten to be present as $WO_3$.

*Sintering.*—Incidental to this work upon the relation between the feldspars, we made a great many observations upon the sintering of powdered minerals, both crystalline and vitreous, of natural and artificial composition. While the results have not enabled us to offer positive conclusions of importance, they are worth a note in passing,

Powdered glasses sinter slowly or rapidly several hundred degrees below the melting temperature of crystals of the same composition. When the viscosity is relatively slight (anorthite) crystallization begins at a low temperature and proceeds very rapidly, the sintering probably being due to the interweaving of the crystal fibers during their formation. In viscous glasses (albite) sintering also begins at low temperatures,—

the finer the powder and the slower the heating, the earlier the first traces appear. Long continued heating, even at very low temperatures (700°), yields a perfectly continuous cake (except for the included bubbles) the surface area of which constantly tends toward a minimum. There is no doubt that the sintering of powdered glasses is due to flow in the undercooled liquid and is a phenomenon in liquid viscosity. All the feldspar glasses sintered readily between 700° and 900°, depending on the fineness of the powder and the time.

Powdered crystalline feldspars do not sinter readily below their melting temperature. Indeed we were at first inclined to the view that when only pure, dry, stable crystals are present, they do not sinter however finely they be powdered. We observed the phenomenon in natural albite at 1000° but the crystals were not wholly free from inclusions which may have caused chemical reactions resulting in cementation. Crystalline fluorite also sinters 300° below its melting point, but here we were able to establish a decomposition. Acid fumes were evolved during the experiment and the sintered cake contained 1 per cent of free lime. Our final experiments with long continued heating for specific gravity determinations, however, showed that the purest feldspars we could prepare, even after they had reached their maximum density, still sinter very slowly. Thus $Ab_1An_5$ powder, which was shown by a determination of its specific gravity to be holocrystalline, formed a compact chalky mass in four hours at a temperature about 150° below its melting point; in three days it was as hard as porcelain. Other feldspars showed the same behavior. It is hardly possible that inhomogeneities sufficient to produce diffusion between portions of different concentration, could have existed in these charges. There is considerable indication that some of the crystalline nuclei grow at the expense of others—perhaps through exceedingly slow sublimation—which may account for it.

We made repeated attempts to locate some fixed sintering point which should be characteristic of a particular material by means of continuous measurements of the electrical conductivity, but they all indicated that no such point existed. The conductivity of a dry powder increases enormously after sintering begins and would therefore seem to offer a most sensitive test, but the phenomenon is altogether gradual even with a crystalline feldspar containing only a small percentage of glass. We purpose to extend these observations to other substances

*Conclusions.*—It now remains for us to gather the results together and to draw such conclusions as they appear to justify.

(1) If the melting points are now plotted in a system of

which they form the ordinates, while the percentage compositions of the different feldspars form the abscissas (fig. 12), we discover, within the limits of accuracy of possible measurement at these temperatures, a nearly linear relation: the melting point varies very closely with the composition. We have no maximum, no minimum, no branching of the curve, but from each fusion there separates a solid phase of the same composition as the vitreous matrix. In $Ab_1An_6$ it will be remembered that this was proved by the separation and analysis of the two phases; in $Ab_1An_2$ partial crystallization was accomplished in the first cooling and the remainder in a subsequent reheating and cooling, the two groups of crystals proving optically identical; a small quantity of $Ab_4An_1$, which admits of absolute identification optically, was crystallized out of a melt of that composition and readily recognized. Moreover, evidence to show that the same phase always separated was likewise presented.

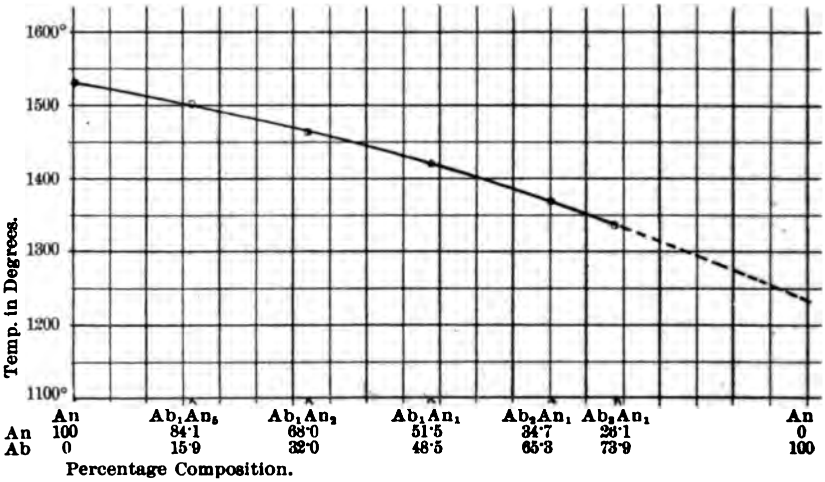

Fig. 12.

Stated in this way, the relation appears to be a simple additive one in which liquid and solid phases of like composition are stable in all proportions of the components and behave like a series of separate feldspars. But as soon as we consider it with reference to the laws of solution and the phase rule, it can not be explained in this simple way.

First of all, the phase rule tells us at once that we can have no true compound here between the components albite and anorthite, for such a compound would mean one more component and an additional phase in every solution before equilibrium could be established. Moreover, if the mixture had been eutectic in character, the component (albite or anorthite) which happened to be in excess would have crystallized out in each case, causing a continual change in the composition of the remaining glass until the eutectic proportion was reached and the resulting charge would have contained only crystals of one (or, in case of hysteresis, both) of the components and the eutectic. Our curve is continuous and the resulting charges homogeneous for all proportions of the components. Lane's suggestion* that the triclinic feldspars from a eutectic series in which the eutectic proportion is at or near $Ab_2An_3$ is therefore not borne out by our experiments.

Laying aside the eutectic mixture, and passing over to solutions of components which are miscible in many or all proportions, we find a small number of examples, chiefly organic compounds, which have been studied as types by Roozeboom, Küster, Bodländer, Garelli, Bruni, Van Eyk and others, among which our series appears to fall.

*Laws of Solutions.*—From the physico-chemical standpoint, the case we now have in hand closely resembles Küster's problem of 1891.† His measurements were made upon mixtures of organic compounds of low melting point, while ours reached a maximum temperature of 1532°, but we have, between albite and anorthite, an exactly similar series of solid solutions the melting points‡ of which change in nearly linear relation to the percentage of the two compounds which enter into their composition.

This simple linear relation was called by Küster perfect isomorphism, and he formulated the "Rule" which has since borne his name, that the solidifying point of an isomorphous mixture lies on a straight line joining the melting points of the components and can be calculated from the percentage composition of the mixture. If this line proved to be slightly concave or convex, as it did in most cases, imperfect isomorphism was assigned as the cause. To this rule an objection was raised by Garelli§ and elaborated by Bodländer‖—if the solid solution behaves like other solutions, a small quantity of component *B* added to component *A* can only lower the solidifying point of *A* when the solid phase is richer in *A* than the liquid phase. The reasoning is this (Bodländer): let $x_1$ (fig. 13) be the vapor tension curve of component *A* in the liquid state, $y_1$ the solidifying point ($t_1$) of *A*, and $z_1$ the vapor tension curve of solid *A*. Now if a small quantity of *B* is added and the solid phase which crystallizes out contains the same proportions of *A* and *B* as the liquid mixture in which it formed, the vapor tensions of the liquid and solid phases must have been lowered equally and the solidifying point will fall at $y_1$ with the same temperature as the pure solvent. (Equality of vapor tension in the solid and liquid phases determines the temperature of change of state.) If *A* crystallizes alone from *A* + *B*, the vapor-tension curve will continue on to $z_2$ and the temperature of solidification fall to $t_2$; while if the solid phase contains both components but is richer in *A* than the liquid phase, solidification will occur at an intermediate point.

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* Lane, Journal of Geology, XII, ii, p. 83, 1904.

† F. W. Küster, Zeitschr. für Phys. Chem., viii, p. 577, 1891.

‡ Küster measured solidifying points, but we have pointed out above that such measurements lead to no positive result in liquids of such viscosity as the feldspars in which equilibrium is not established during solidification. Undercooling rarely appeared at all in Küster's cases.

§ F. Garelli, La Gazzetta Chimica Italiana, xxvi, p. 263, 1894.

‖ Bodländer, Neues Jahrb. f. Min., Beilage, Bd. xii, p. 52, 1899.

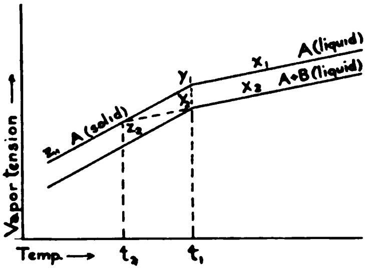

FIG. 13.

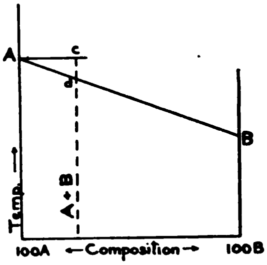

FIG. 14.

Fig. 14 will serve to show the crucial character of the issue raised. The ordinates represent temperatures, and the abscissas percentages of *A* and *B*. Küster finds his solid and liquid phases identical in composition within the limits of experimental error and the solidifying temperature on the line *AB* at a point which can be determined from the proportions of the components—at *d* for example. But the laws of dilute solutions tell us that if the phases are identical in composition, the solidifying point of *A* + *B* must fall at *c*, i. e. must remain the same as for pure *A*.

The temperatures at which Küster's observations were made and their painstaking character leave no doubt as to the validity of the experimental fact. Neither can it be objected that Küster's solutions were not sufficiently dilute to reveal the true relation, for the observations upon naphthaline and $\beta$-naphthol have been repeated by Bruni* with very dilute solutions of one of the components in the other, and completely verified.

Now the laws of solutions hold for solid solutions even for moderately high concentrations (Bodländer) when the components are not isomorphous, and on the other hand even liquid crystals, when isomorphous, follow Küster's Rule more nearly than the law of solutions.

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* G. Bruni, Atti della Reale Accademia dei Lincei, series 5, vii, p. 138, 1898.

An extended discussion of existing data from this standpoint would involve us in unnecessary detail, but there can be no question that Kuster's Rule represents the data which have been gathered upon isomorphous mixtures—at least approximately—while the laws of dilute solutions appear to fail of application there. On the other side, the Rule admits of no independent theoretical derivation. Van't Hoff* suggests that judgment be suspended pending the accumulation of further data and intimates that the close similarity of chemical composition and molecular structure in compounds which form isomorphous mixtures, gives them an unusually close interrelation, and their influence one upon the other may render a simple theoretical treatment very difficult.

Our case is especially interesting when considered from this standpoint, but it distinctly emphasizes the difficulty rather than helping toward its solution: (1) Although the chemical reactions of albite and anorthite are not of such a character as to prove or disprove a close analogy between them, a comparison of their formulas certainly does not suggest an isomorphous relation. If their formula weights represent true molecules, they possess the same number of atoms to the molecule ($NaAlSi_3O_8$, $CaAl_2Si_2O_8$) and the group $Si_2O_8$ in common, but the remaining atoms taken separately are not mutually replaceable. (2) The melting points of the components in the feldspar series are very far apart—more than 300°—while Küster's organic mixtures were all included within a narrow temperature interval (2° to 56°). For reasons which will appear presently, both Garelli† and Roozeboom have pointed out that the farther apart the melting points of the components, the less probable is the linear relation. (3) The homogeneity of the solid phase is established within 1 per cent by the optical examination of the slides. Moreover separate chemical analyses of the solid and liquid phases of the mixtures $Ab_1An_5$ in an exceptionally favorable case showed still closer identity of composition.

It appears altogether improbable that the laws of solutions can apply in the face of so extreme a controverting case.

If it has proved difficult to bring the isomorphous mixture within the general laws of solutions, a most satisfactory theoretical derivation of the conditions of equilibrium in such mixtures has been developed by Roozeboom. No other principle is required than the second law of thermodynamics as applied to solutions by Gibbs:—A system of substances will be in equilibrium for a particular pressure when the thermodynamic potential ($\zeta$-function) of the system is a minimum. The scheme of representation is the graphical one proposed by van Ryn van Alkemade* and is itself a powerful instrument of analysis in this field.

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* Van't Hoff, Vorlesungen üb. Theoret. u. Phys. Chem. (Braunschweig 1901.) Part II, p. 64.

† F. Garelli, loc. cit.

Roozeboom distinguishes three general classes of isomorphous mixtures:

(1) The components are miscible in all proportions from 0 to 100 per cent in both solid and liquid phases.

(2) Miscibility is limited to certain concentrations.

(3) More than one type of crystal occurs.

In the feldspars we are concerned with the first class only, but here also Roozeboom distinguishes three possible types:

Type I. Melting (or solidifying) points of the mixtures lie on a continuous curve joining the melting points of the components and containing neither maximum nor minimum.

Type II. The curve contains a maximum.

Type III. The curve contains a minimum.

* Zeitschr. f. Phys. Chem., xi, p. 289, 1893.

Except for the suggestions of Vogt to which reference has been made, this method seems not to have been utilized for the study of mineral solutions before. A brief outline of it will therefore be given here.

In a system of rectilinear coördinates (fig. 15) the ordinates may represent the potential of a particular system—(Gibbs' ζ-function, not directly measureable) and the abscissas the number of gram-molecules of solvent (water for example) supposed to contain 1 gr. mol. of solute. In other words, every point of the curve represents a solution of which the $x$ coördinate is concentration and the $y$ coördinate the potential. The conditions of pressure and temperature are assumed constant for a particular diagram.

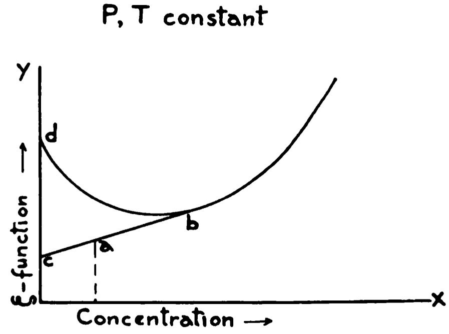

FIG. 15.

Every such curve for substances soluble in all proportions will be convex downward, otherwise there would be some particular point on the curve which would not represent a minimum potential for a particular composition and the solution would tend to separate into two, the mean potential of which would be lower.

The condition for equilibrium between such a solution and its solid phase (pure salt) may now be readily found. Lay off on the ζ-axis a distance equal to the potential of the solid salt and from the point so obtained draw a tangent to the curve. This tangent is the locus of minimum potential (stable systems) for any composition. At the point $a$ for example, we have a saturated solution containing the number of gr.-mol. of solvent indicated by the corresponding abscissa and the proportion $\frac{ac}{cb}$ of salt, the balance of the salt remaining in solid phase. At $b$ we have the saturated solution with all the salt included; to the left of $b$ upon the curve, supersaturated solution; and to the right unsaturated solution. With increase of temperature the form of the curve changes and $c$ approaches $d$, the melting point of the salt.

These types are for the moment purely hypothetical and are a product of the method of analysis, though they are being rapidly identified for various isomorphous pairs by pupils of Roozeboom and by others.

The method of reasoning which yields these three possible types will be briefly described with the help of the van Alkemade graphical analysis:

If we indicate the potential ($\zeta$) of a particular mixture by the length of the ordinate (fig. 16), and the number of molecules of $A$ and $B$ by subdividing the horizontal axis ($A+B=100$) in the proper proportion, assuming atmospheric pressure and constant temperature for each diagram, then every point within the coördinates represents a particular phase of known composition and potential. Suppose now (Roozeboom) a temperature is assumed above the melting point of the higher-melting component, clearly, whatever the composition, only the liquid phase can have a stable existence. If potential difference represents the measure of the tendency to change and the tendency of all change is toward the minimum potential, for this temperature all change will be toward the liquid, and the potential of a solid, if one existed there, would be greater than that of the liquid for all compositions —hence the curve $S$ (solid) above the curve $L$ (liquid) throughout.

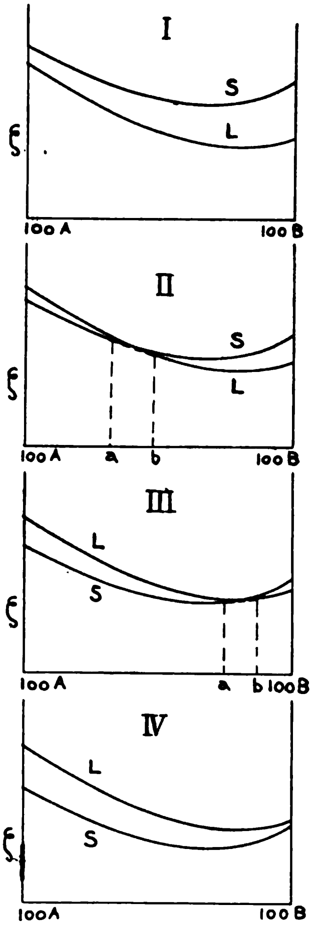

FIG. 16.

Suppose the potential to be lowered to a point where crystallization can begin, the tendency to melt no longer obtains for all compositions, the two curves will be displaced relatively and, being of different form, will intersect. Draw a common tangent to the two curves and apply van Alkemade's reasoning above noted. The trend of the potential of both phases between the points of tangency, i. e. of all mixtures between these limits of composition, is toward the minimum represented by this tangent. Crystallization will then begin at *a* (fig. 16, II) with the mixture richest in the higher melting component, crystals of composition *a* will be in equilibrium with the liquid phase *b* in all proportions and solidification (or melting) will not take place at a single temperature but through a range of temperature. If we now plot the length of the abscissa corresponding to *ab* in a separate diagram with the observed temperature range of solidification, adding all the other possible cases which will arise from the continued displacement of the ζ-curves, we arrive at the accompanying diagram (fig. 17) of Roozeboom's type I. Types II and III appear in the same way when the form of the ζ-curves changes as indicated in figs. 18 and 19.

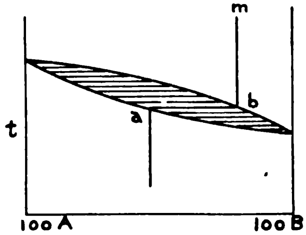

Fig. 17.

The physical side of the system of reasoning is readily inferred from the figures. If we start with a mixture of the composition indicated by *m*, (fig. 20) and temperature above the melting point, crystallization will begin at *a*, the separating crystals will have the composition *b*, while that of the remaining melt approaches *d*. Upon cooling to *e*, solidification ends with crystals of this composition. Melting is exactly the reverse operation. Whether these first crystals of composition *b* remain stable as such or undergo solid transformation or wholly or partly redissolve, appears to remain undetermined in any general way by Roozeboom's theory and may be radically influenced by accompanying phenomena like viscosity and undercooling: if a liquid mixture of composition *a* undercools to *e* before crystallization begins, crystals of composition *e* will appear *and no others* (provided the release of heat of fusion does not raise the temperature above *e*). Such a situation is certainly unavoidable in viscous mixtures like the feldspars and accounts very well for the homogeneous solidification observed by us. This would classify the feldspars with type I of Roozeboom's series. A comparison of our melting point curve with figs. 17, 18 and 19 shows this to be the only type under which it could possibly fall. There is no trace of a maximum or minimum in the feldspar curve. Vogt's expectation that they would fall under type 3 therefore fails of fulfilment from our experiments.

That our curve so closely resembles one branch of Roozeboom's typical curve is remarkable. The difficulties of observation, in those portions of the curve where the viscosity becomes so disturbing, are too great to enable stress to be laid upon the form which our curve happens to take there, but

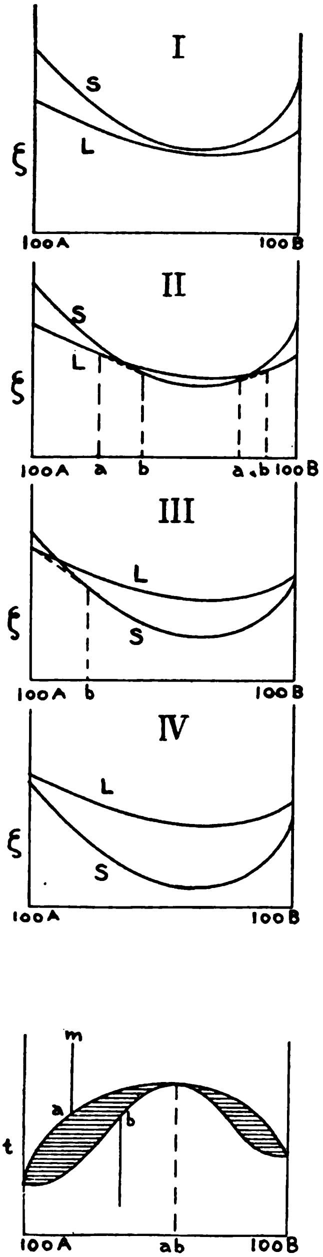
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FIG. 18.

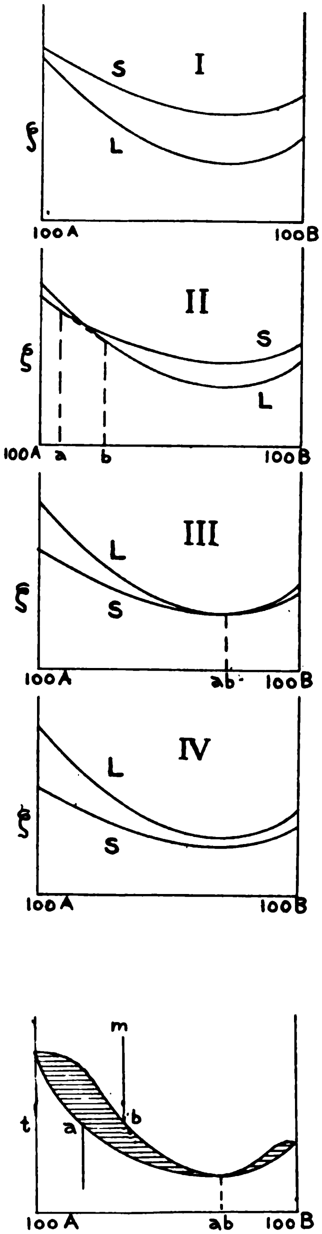
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FIG. 19.

near the anorthite end of the series its slight convexity is unquestionably real.

It should be added that Prof. Iddings has found slight traces of inhomogeneity (less than 1 per cent) in the slides of several of our intermediate feldspars. Crystals have been found which were evidently of the earliest formation and with one exception were more calcic than the body of the charge, as Roozeboom's theory would lead us to expect. The exception was an occurrence of tiny plates of $Ab_4An_1$ discovered in a charge of $Ab_1An_4$. The extremely small quantity of the optically different feldspar, the fact that it could not be found in all the slides and that in one case a less calcic feldspar appeared, suggest that the inhomogeneity may have been of other origin—perhaps merely a consequence of the tremendous difficulty in mixing a homogeneous charge where ultraviscosity precludes stirring, for example. The chemical analyses of the solid and liquid phases, it will be remembered, showed identical composition within the limits of experimental error.

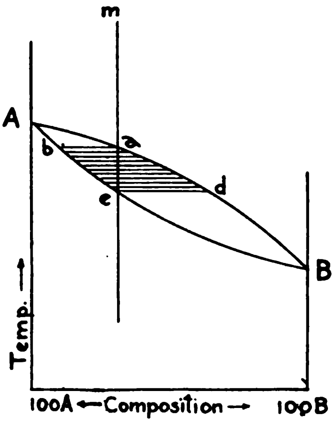

Fig. 20.

It is clear that if Roozeboom's theory is valid, the line of the melting points can not become perfectly straight unless the ζ-curves for the solid and the liquid phases can be superposed point for point throughout, i. e., are identical. This would mean that the energy content per gr.-mol. of solid and liquid phase was the same for all compositions, i. e. that all mixtures, and the components separately should have the same melting point,—a case which is known (Roozeboom, *d*- and *l*-camphor oxime) but is certainly confined to optical antipodes.

Another reason for supposing the case to be much less simple than a mere linear relation with equilibrium between solid and liquid phases of identical composition, appears at once from a direct application of the phase rule. A necessary condition for equilibrium in any mixture is that the number of phases exceed the number of components by two. If the solid and liquid phases are homogeneous, the number of phases (counting vapor) is only three and equilibrium can not obtain there.

Reviewing this discussion briefly: The triclinic feldspars are solid solutions and form together an isomorphous series. It is a sufficient condition for the latter that the curve of melting points is continuous (Bruni, loc. cit.). Like Küster's curves for organic compounds, the curve of melting points does not follow van't Hoff's law of dilute solid solutions and does approximate closely to a straight line joining the melting points of the components. The case appears to fall under type I of Roozeboom's theoretical classification of isomorphous mixtures, in which case the line can not become exactly straight unless the melting points of the components are nearly or quite identical, nor the solidification absolutely homogeneous without reducing the number of phases to three and destroying the equilibrium. The theory also accounts for an absence of sharpness in the intermediate melting points of the feldspars, but the fact that this lack of sharpness culminated in albite instead of terminating there shows that the viscosity was the chief factor in our difficulties from this cause. Albite was clearly shown to melt through a variable range of 150° or more, while the intermediate feldspar bytownite ($Ab_1An_3$) melted almost as sharply as anorthite. The fact that practically no differences of composition could be detected in our melts we attribute to the effect of viscosity and consequent undercooling, which resulted in crystallization invariably taking place at much too low a temperature for equilibrium to become established between the solid and liquid phases at any stage of the crystallization process.

(2) When the specific gravities are plotted, like the melting points, as a function of the composition (fig. 21), the isomorphism of the feldspars is strongly confirmed. The curve indicates a perfectly continuous relation which the successful preparation of chemically pure albite enabled us to follow through to the end. The order of accuracy is also extraordinarily high throughout by reason of the chemical purity of all the preparations and the consistent effort made to obtain complete crystallization, even with the more viscous feldspars. Several of the charges were treated for two weeks or more consecutively, then removed for a determination, then replaced in the furnace for another week, in order that we might assure ourselves from the consistent reappearance of the same value that a maximum and therefore holocrystallization had been reached. It is of some practical importance to note in passing, that preparations which appeared completely crystalline in the slides frequently proved not to have reached their maximum specific gravity. It is very difficult to detect the last trace of glass with the microscope.

If our confidence in these determinations is justified, the form of the specific gravity curve is very significant. It was pointed out by Retgers* that if the isomorphous mixture is merely a "mechanical aggregate," the volume of which remains exactly equal to the sum of the volumes of the components, then the specific volume curve of the mixtures for percentages by weight of the two components must be a straight line. He also offers a number of isomorphous pairs for which he finds the specific volume curves to be straight lines, in support of his hypothesis that this relation is general. Our values when plotted in this way (fig. 22) also give a straight line with maximum variations amounting to 0·005, which is probably not greater than the aggregate error in the syntheses and in the determinations of the specific gravity.

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* J. W. *Retgers, Zeitschr.* für Phys. Chem., iii, p. 507, 1889.

In spite of this apparent corroboration, it does not seem to us that Retgers was quite justified in assuming that this relation is entirely without limitation. The temperature at which the specific gravity is determined is so far below the temperature of solidification (in our case, more than 1,000°) that the density at 25° will depend to a considerable degree upon the coefficient of expansion of the material as well as upon composition or molecular structure. The coefficient of expansion will, in general, differ for different substances, and is not, in general, a linear function of the temperature. Considering Retgers' generalization in the light of these facts, the relation of the specific gravities at 25° would be necessarily continuous but not necessarily linear.

The specific gravities of the glasses are also plotted (fig. 21) to show the divergence from the line of the crystals toward the albite end of the series, i. e., as the percentage of albite increases, the density of the glass is diminished more than that of the crystals.

There is nothing new in the conception of isomorphism in the feldspars, but the positive character of our experimental results makes them of more than ordinary interest by reason of the fact that so good authorities on the subject as Fouqué and Lévy have passed upon it adversely on the basis of optical evidence derived from artificial preparations. More recently Viola,* has declared that the optical evidence is insufficient to prove isomorphism in the natural feldspars.

The melting points and specific gravities are brought together in a convenient table here.

| Feldspar | An | $Ab_1An_5$ | $Ab_1An_2$ | $Ab_1An_1$ | $Ab_2An_1$ | $Ab_3An_1$ | Ab |
|---|---|---|---|---|---|---|---|
| Melting temp. | 1532° | 1500° | 1463° | 1419° | 1367° | 1340° | |
| Sp. gr. (crystals) | 2·765 | 2·733 | 2·710 | 2·679 | 2·660 | 2·649 | 2·605 |
| Sp. gr. (glass) | 2·700 | 2·648 | 2·591 | 2·533 | 2·483 | 2·458 | 2·382 |

(3) In the melting of albite and microcline we appear to have substantial evidence of a phenomenon which is unfamiliar both to physics and to mineralogy. Microscopic crystals of a homogeneous compound, when slowly heated, were shown to persist for 150° or more above where melting began, the amorphous melt remaining of the same order of viscosity as the rigidity of the crys-

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* Loc. cit.

tals. By careful observation, curves were also obtained showing that the absorbed heat of fusion was distributed over this interval.

From the experimental standpoint a substance of this kind can hardly be said to have a melting point but passes gradually from crystalline to amorphous at temperatures which can be

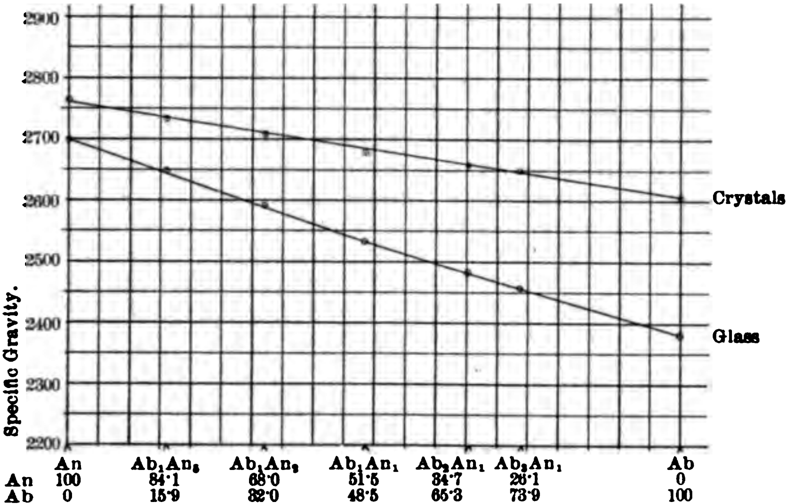

FIG. 21.

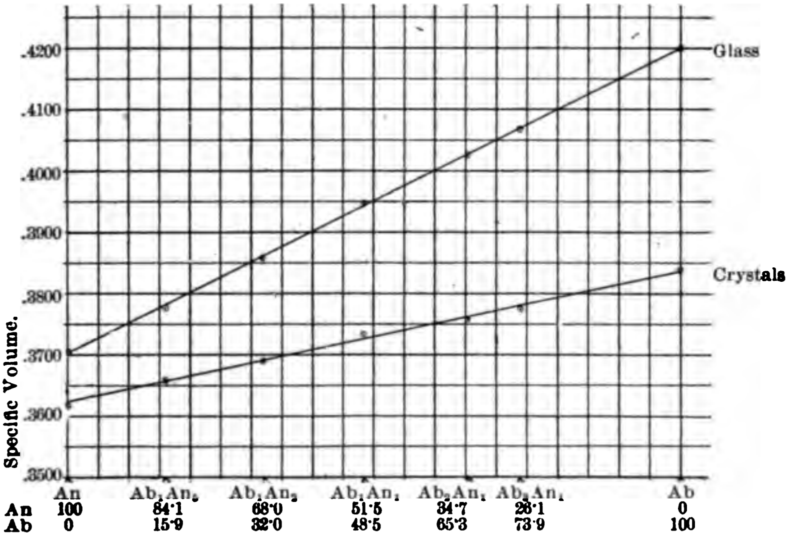

FIG. 22.

considerably varied by merely changing the rate of heating. In moderate charges of albite or orthoclase at atmospheric pressure this melting began so slowly that it was not possible to locate even approximately a lowest temperature for the beginning of the change of state. As a matter of definition, this minimum temperature above which melting will continue (for a given pressure) more or less rapidly according to the conditions, is the "melting point," whether it can be located or not, so far as the equilibrium of the system is concerned, and the crystals which continue to exist unmelted at higher temperatures appear to form a metastable phase, perhaps comparable with that of a crystalline solid when heated above the "Umwandlungstemperatur" without immediate change of crystal form. It is also possible that the mass is fluid when heated above the melting point but that deorientation of the molecules is delayed by viscosity. This metastable stage can easily extend over 150° in albite and orthoclase and would persist for days in the lower position of this range.

(4) We also found that viscous and poorly conducting melts which solidify only after considerable undercooling, do not give constant solidifying points. The solidifying point must not be used, therefore, without great caution as a physical constant; it bears no relation whatever to the melting point unless equilibrium is reëstablished before solidification is complete—a condition which rarely obtains and often can not be produced in viscous mineral melts. Especial attention is directed to this because of the importance of the lowering of the solidifying point in the study of solutions, and the possibility of its application to mineral solutions recently suggested by Vogt.*

(5) Incidental to the experimental work upon the feldspars we were able to establish the fact that there are no differences of density in the feldspar glasses due to the rate of cooling, which are greater than our errors of observation (±·001). Also that powdered feldspar glasses sinter tightly at temperatures as low as 700°,—a phenomenon which we ascribe to flow in the undercooled liquid. Pure, dry, crystalline feldspars also sinter at least 150° below their melting temperature, but very slowly. This may be due to certain crystalline nuclei growing at the expense of others; perhaps through exceedingly slow sublimation.

Also that powdered feldspars, when exposed to the atmosphere, adsorb moisture, in quantities of an order of magnitude equal to those usually quoted in analyses (Dana's System of Mineralogy, p. 314). It is therefore altogether possible that the significance of this moisture has been mistaken. It cannot be completely driven off below a red heat.

Geophysical Laboratory, Carnegie Institution,
Washington, D. C., November, 1904.

* J. H. L. Vogt, loc. cit.

## ART. VIII.—*On the Progress of the Albatross Expedition to the Eastern Pacific;* by ALEXANDER AGASSIZ.

**[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Lima, Nov. 28, 1904.]**

THE Albatross, under command of Lieut. Commander L. M. Garrett, left San Francisco on the 6th of October and arrived at Panama the 22d. On her way along the coast Professor C. A. Kofoid took advantage of the opportunity for making surface hauls with the tow nets as well as vertical hauls, generally to a depth of 300 fathoms. A large amount of pelagic material was thus collected, not at a great distance from the coast however. Off Mariato Point the Albatross made two hauls in the vicinity of the stations where in 1891 she found "modern green sand," in about 500 and 700 fathoms. It was interesting to find the green sand again, as the specimens collected in 1891 were lost in transit to Washington. I am fortunate in having as assistant for this trip Professor Kofoid, who has had great experience in studying the Protozoa both in fresh water and at sea. He has been given charge of the collection of Radiolarians and Diatoms and of other minute pelagic organisms; and he will prepare a report on the results of that branch of the Expedition.

The Albatross arrived at Panama on the 22d, she was coaled and provisioned at once, on my arrival at Panama on the 1st of November I found her ready for sea, and on the 2d we left for Mariato Point to make a few additional trawl hauls in the region of the green sand. In both the hauls made off Mariato Point green sand was found, but not in the quantity obtained in 1891.

From Mariato Point we made a straight line of soundings towards Chatham Island in the Galapagos, intersecting the ring of soundings we made northeast of the Islands in 1891. The deepest point of the line (1900 fathoms) was found about 100 miles S.W. of Mariato Point. The bottom then continued to show about 1700 fathoms for nearly 200 miles and then shoaled very gradually to 1418 fathoms about 80 miles from Chatham Island. From this point it sloped quite rapidly, the 1000-fathom line being not more than 60 miles from Chatham Island. We ran a short line south of Hood Island and found a somewhat steeper slope to that face of the Galapagos, reaching over 1700 fathoms in a distance of less than 50 miles; the bottom then remained comparatively flat, attaining a depth of 2000 fathoms about 100 miles farther south. This depth we carried eastward on a line to Aguja Point. When half way the soundings had increased to over 2200 fathoms, and remained at about that depth to within 60 miles of the coast, when the depth rapidly shoaled. From Aguja Point we ran a line of soundings to the S.W. to a point about 675 miles west of Callao; on this line the depths gradually increased from 2200 fathoms, 100 miles off the Point, to nearly 2500 fathoms. On running east to Callao the depth soon increased to about 2600 fathoms, and at a distance of about 80 miles off Callao we dropped into the Milne-Edwards Deep and found a depth of over 3200 fathoms. We spent a couple of days in developing this Deep, making soundings of 1490, 2845, 458, 1949, 2338, and 3120 fathoms; showing a great irregularity of the bottom within a comparatively limited area of less than sixty miles in diameter. Thus far all our soundings have been made with the Lucas Sounding Machine.

In the Panamic Basin to the northeast of the Galapagos we trawled only off Mariato Point, but we occupied ten stations with the tow nets, hauling both at the surface and at 300 fathoms, and vertically from that depth; we also continued this pelagic work at nearly all the stations (35) from the Galapagos to Callao.

When off Chatham Island we began to trawl, and used the tow nets regularly, occupying 20 stations. The nets were in charge of Mr. F. M. Chamberlain. The pelagic collections, as a whole, are remarkably rich. They are especially noteworthy for the great variety and number of pelagic fishes obtained inside the 300-fathom line at a considerable distance from shore —from 300 to 650 miles. Many of these fishes had been considered as true deep-sea fishes, to be obtained only in the trawl when dredging between 1000 and 1500 fathoms or more. On one occasion the tow net brought up from 300 fathoms, the depth being 1752 fathoms, no less than 12 species of fishes; of some species of Myctophum we obtained 18 specimens; of another, 37; of a third, 45; in all nearly 150 specimens. On other occasions it was not uncommon to obtain 8 or 10 species, and from 50 to 100 specimens. Among the most interesting types obtained in the tow net I may mention as coming from less than 300 fathoms Stylophthalmus and Dissoma, both of which Chun considers as deep-sea fishes, found in depths of 600 to 4000 meters; also a species of Eurypharynx obtained for the first time in the Pacific. Stylophthalmus I had caught in the tow net also in 1900, during the tropical Pacific Expedition of the Albatross, in depths of less than 300 fathoms. In the lines we ran across the great northerly current which sweeps along the coasts of Peru and Chili and is deflected westward at the easterly corner of the Galapagos Islands, we obtained with the tow nets an unusually rich pelagic fauna at depths less than 300 fathoms. We collected a number of Schizopods, among them many beautifully colored Gnatheuphausiæ, pelagic Macrurans; huge, brilliant red Copepods, as well as many other species of blue, gray, mottled and banded Copepods. Lucifer and Sergestes were abundant in many of our hauls. Many species of Amphipods were collected, Hyparids without number, especially where the surface hauls were made among masses of Salpæ, which, on several occasions, formed a jelly of Tunicates. Several species of Phronimæ also occurred constantly in the tow nets. Sagittæ were very numerous, a large orange species being noteworthy. Several species of Tomopteris, some of large size and brilliantly colored, violet or carmine with yellow flappers, and two species of Pelagonemerteans. Two species of orange-colored Ostracods were also common, one having a carapace with a long spiny appendage. We obtained several species of Pelagic Cephalopods, Cranchia and Taonis among them. Two species of Doliolum also occurred, but they were never as abundant as the Salpæ, two species of which often constituted the whole contents of the net.

In the surface and deeper tows we procured also a number of Acalephs. We have thus far collected more than 50 species of Medusæ and Siphonophores, many of which have been figured by Mr. Bigelow, differing from those of the 1891 Expedition. Atollæ and other deep-sea Medusæ were common within the 300 fathom line.

The Salpæ guts gave us, in addition to the finer tow nets, immense collections of Radiolarians, Diatoms, and Dinoflagellata, many of which have been considered to live at great depth and upon the bottom. The number of Diatoms found in this tropical region is most interesting. They have usually been considered as characteristic of more temperate and colder regions. On several occasions the surface waters were greatly discolored by their presence, and the extent of their influence on the bottom deposits is shown by the discovery of a number of localities where the bottom samples at depths from 1490 to 2845 fathoms, in the track of the great Peruvian current, formed a true infusorial earth.

The tow nets also contained many species of Hyalca, Cymbulium, Styliolus, Cleodora, Tiedemannia, Clio, and the like. On one occasion the mass of the pelagic hauls consisted entirely of small brown Copepods, the contents of the tow nets looking like sago soup. Another time Sagittæ, Salpæ, Diliolum and Liriope, all most transparent forms, formed the bulk of the tow net's catch. Again another time, Firoloides and Carinarias constituted the bulk of the haul. These catches, coming on successive days or interrupted with hauls of more than mediocre quality, show how hopeless it is at sea to make any quantitative analysis of the pelagic fauna and flora at any one station within the influence of such a great oceanic current as the Chili and Peruvian stream.

Hauls of the trawl made at the western extremity of our lines brought us within the area of the manganese nodules, with its radiolarian ooze mud, Cetacean earbones and beaks of Cephalopods; nothing could stand the damaging work of these nodules in grinding to pieces all the animal life the trawl may have obtained. Down to the depth of 2200 fathoms or so the bottom was constituted of Globigerina ooze, its character being more or less hidden when near the coast by the amount of detrital matter and terrigenous deposits which have drifted out to sea.

North of the Galapagos we found vegetable matter at nearly all the stations, and between the Galapagos and Callao such material was not uncommon in the trawl.

Beyond the line of 2200 fathoms dead Radiolarians became quite abundant on the bottom, as well as in the mud of the manganese nodules, though among the nodules it was not uncommon to find an occasional Biloculina. Many of the dead Radiolarians found on the bottom Mr. Kofoid obtained from the guts of Salpæ swimming near the surface or within the 300 fathom line in the tow nets sent to that depth. The same is the case with many of the Dinoflagellata which have been considered as deep-sea types. In our tow nets from 300 fathoms we found very commonly Tuscarora, Tuscarosa, Aulospira and others. In depths of 300 fathoms to the surface, the tow net was rich in Tintinnidæ, either dead or moribund Planktionellæ, and Dinoflagellata. Among the Dinoflagellata there were 10 species of Ceratium, 9 of Peridinidæ, Goniaulix, Phalacrona, Pyrocystis, Cytterocyla, Undella and Dictiocystus. On the surface Planktionella sol predominates, with Asteromphale, Bidolphia, and Sunidia thalassothrix. Among the Dinoflagellata we obtained 12 species of Ceratium, 5 of Peridinium and 22 species of other Peridinidæ; among the Tintinnidæ were a number of Sticholonga; among the Acantheriæ were especially to be noticed Acanthometra, Acanthostaurus, Amphilonche, Collozoum, Thalassicola, and a number of Chirospira Murrayana and a few Challengeridæ.

Our trawls brought up from the bottom many interesting fishes, among which I may mention Benthoptemis, Ipnops, and a few bat fishes, all, thus far, described by Mr. Garman from the 1891 Expedition. I may mention also a Chimæra, different from the Chili species. The fishes have been admirably cared for by Dr. J. C. Thompson, U. S. N.

Among the Crustacea, Lithodes, Munidopsis and many Macrurans, all well known species of the 1891 Expedition, we found a few Mollusks, and a few interesting genera of Tubiculous Annelids. Compared to the 1891 Expedition, few starfishes and brittle stars were obtained, and still fewer Sea Urchins, only one species of Aceste and one of Aerope, a marked contrast to the numerous Echini collected in the Panamic Basin in 1891. We obtained, however, a magnificent collection of Holothurians, nearly every species occurring in the Panamic Basin being found in numbers in our track south of the Galapagos, in the wake of the great Chili-Peruvian current and at considerable depths. On one occasion, at station 4647, in 2005 fathoms, we obtained no less than 16 species of Holothurians, among them brilliantly colored Benthodytes, Psychropotes, Scotoplanes, Euphronides, and the like. At station 4670, in 3209 fathoms, we obtained 6 species of Holothurians. At station 4672, in 2845 fathoms, we obtained also very many specimens of three species of Ankyroderma, a large Deima, 2 species of Scotoplanes, 2 of Psychropotes, with a number of young stages of that genus, repeating thus the experience of the Challenger, which found Holothurians at great depth, in abundance not only in the number of specimens but also of species, though the Challenger did not in any locality obtain as many as we did at station 4647. Mr. Westergren made a number of sketches of the species which were not obtained in the 1891 Expedition. We also collected in the trawl a number of deep-sea Actinians, none different, however, from genera previously found in the Panamic district. We obtained also a few Pennatulids, Gorgonians, and Antipathes, and a very considerable number of silicious sponges, usually associated with the Holothurians found in deep water in the track of the Peruvian current. In the track of the current at not too great distances from the coast we invariably brought, even from very considerable depths, sticks and twigs and fragments of vegetable matter. On two occasions we brought up in the trawl specimens of Octacnemus. The trawl had been working at 2235 and at 2222 fathoms. Both Moseley and Herdman described this interesting Ascidian as attached to the bottom by a small peduncle. While the presence of the peduncle cannot be denied, yet its attachment, if attached at all, must be of the slightest, its transparent, slightly translucent body, with its eight large lobes, suggesting rather a pelagic type than a sedentary form. This Ascidian was discovered by the Challenger west of Valparaiso.

Mr. Chamberlain made two daily observations of the density of the water, and found the same discrepancies between our observations and those of 1891, and those given by the Challenger and in the German Atlas of the Pacific Ocean. Whenever we took a serial temperature, he also determined the density at 800 fathoms. We occupied six stations for the serial temperatures, two on the western termini of the lines normal to the coast across the great Peruvian current, two in the center of the current, and two at a moderate distance from the coast. These serials developed an unusually rapid fall in the temperature between the surface and 50 fathoms—nearly 12° at the western extremity of the northern line, the temperature having dropped from 71·7° at the surface to 59·2°. At 200 fathoms it was 51°, and at 600 fathoms it had dropped to 40·7°, the bottom temperature at 2005 fathoms being 36·4°. The temperature of the station in the central part of the current in 2235 fathoms agreed with the western series. At the eastern part of the line in 2222 fathoms, with a bottom temperature of 36·4°, the surface being only 67°, we found again a close agreement at 50 and 100 fathoms, the lower depths at 400 and 600 fathoms being from one to two degrees warmer than the outer temperatures. On taking a serial from the surface to 100 fathoms, we found that the greatest drop in temperature took place between 5 and 30 fathoms.

The temperatures of a line running due west from Callao showed a very close agreement both at the western end of the line about 780 miles from the coast and in the central part of the line, as well as in the shore station about 80 miles from the coast in 3209 fathoms. The bottom temperature in nearly all the depths we sounded was 36°, a high temperature for that depth. I do not make at present any comparison with the serials taken in the Panamic District in 1891 until we shall have completed our lines to the south and to the west.

We leave for Easter Island on the 3d of December, where we shall coal, and from there go to the Galapagos and thence to Manga Reva and Acapulco, where we ought to arrive in the early days of March.

The changes made in the working apparatus of the Albatross under the superintendence of Lieutenant Franklin Swift, U. S. Navy, have proved most satisfactory. The alterations in the main drum and the device for preventing the piling of the wire on the serging drum and the accompanying shock, have greatly reduced the risk of breaking the wire rope when trawling at great depths. The wire rope has proved an excellent piece of workmanship, and has worked admirably in the comparatively deep water in which most of our trawling has been done thus far. A new dredging boom has also been installed, and everything relating to the equipment of the Albatross has been carefully overhauled.

Lieut. Commander L. M. Garrett has been indefatigable in his interest for the Expedition; the officers and crew have been devoted to their work; and the members of the scientific staff have carried out most faithfully their duties of preparing and preserving the collections thus far made.

We hoped to be docked at Callao, but owing to the prolonged occupation of the dock by a disabled steamer and the uncertainty of its becoming free within reasonable time, we decided to proceed without further delay to Easter Island and continue the Expedition as we are.

## ART. IX. — *Measurement of Self-Inductance;* by J. B. WHITEHEAD and H. D. HILL.

THE absolute measurement and comparison of self-inductance has within the last few years become a problem of increasing importance. The best known method and that most generally used is the Rayleigh method. However, this necessitates very intelligent and careful work to obtain results concordant to one per cent. What seem to be the most accurate methods are various modifications of the Wheatstone bridge using alternating currents with an electrodynamometer, telephone, or optical telephone as the measuring instrument.

In January, 1898, Professor Rowland* published a brief description of some twenty-six methods for the measurements and comparison of self-inductance capacity and mutual inductance. These methods are mostly of the Wheatstone bridge type and depend upon the use of an alternating current and an electrodynamometer. As only a few of them have hitherto been tried, it was deemed desirable to systematically test them and determine their value, particularly in regard to the measurement of self-inductance. Such is the aim of the present investigation.

### *Source of current and frequency determination.*

Since the value of the self-inductance or capacity as given by many of the methods depends upon the square of the current frequency, it was necessary to secure a current of harmonic wave form whose period was as constant as possible, and to devise a method of accurately determining that period at the moment of adjustment. This was very satisfactorily accomplished. In the deduction of the formulæ for all the methods the assumption is made that we have a simple harmonic electromotive force. In general an alternating current supplied by a dynamo has not only its fundamental period but also the odd upper partials. However, a generator constructed without too much iron and properly wound, if the field is not very strongly excited, will give a very good sine wave; especially if the resistance in the circuit contains self-inductance and no iron. These requirements were well satisfied by the dynamo used, which gave a very good sine wave. The alternator was constructed at the University. Its armature consisted of twelve coils fastened flat on a German silver plate revolving between twelve field pieces producing six poles. This dynamo was coupled directly to a direct current Crocker-Wheeler motor. As long as the load on the dynamo was not varied the speed remained very constant. Greater constancy of speed was secured by operating the motor from storage batteries. The voltage furnished by the alternator could be controlled by slightly altering the strength of the field. For the determination of the frequency a chronograph was used. A kind of speed counter was connected to the shaft of the dynamo and a contact so arranged that in every ninety-seven revolutions of the dynamo armature a circuit was closed and a record made on the chronograph sheet. The chronograph was set up close to the rest of the apparatus and by means of a thread the pen could be raised for an instant from the sheet and so the exact time of making an adjustment could be readily noted. By interchanging the gear wheels the cylinder of the chronograph was made to run at about three and one-half times the customary speed. The distance between the checks indicating the seconds was so increased to over five and one-half centimeters.

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* Phil. Mag. [5], xlv, 66–85, 1898.

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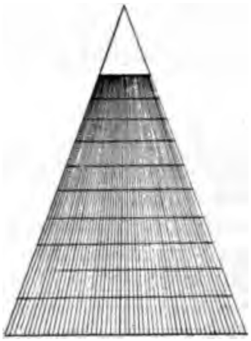

A scale similar to that shown in fig. 1 was then constructed, consisting of fine lines scratched on transparent celluloid and blackened with India ink. By means of this scale it was possible to read the chronograph sheet directly to fiftieths of a second and to estimate to five hundredths. However, in reading a chronograph sheet as exactly as this, certain precautions must be taken. First, the checks indicating the seconds should be sharp and distinct. Secondly, an error may arise if the chronograph does not run quite regularly. This can generally be remedied by properly adjusting the governor. By this method the frequency could be quite accurately determined, to 1/10 per cent or closer, if the sheet was read with sufficient care. It is to be noted that if sidereal seconds are recorded on the chronograph sheet they should be reduced to solar seconds, otherwise an error of 3/10 per cent is introduced in the absolute value of the frequency and, therefore, of 6/10 per cent in the value of self-inductance.

### *Apparatus.*

*Electrodynamometer.*—A Rowland electrodynamometer was used. The self-inductance of the fixed coils was ·0165 henry, and of the hanging coil ·0007 henry.

*Resistances.*—In the measurements of self-inductance with alternating currents, ordinary resistance boxes are of little or no value owing to the electrostatic capacity of the doubly wound coils. Except in the case of a few determinations with Method 25, all the resistances used were made of a special German silver resistance wire, B. and S. gauge, Nos. 30 and 27. This wire was not doubled, but wound continuously in one layer on slates or pieces of micanite, each slate containing about 2000 ohms conveniently subdivided. The self-inductance and capacity of such resistances is entirely negligible. For fine adjustment a small resistance box was constructed differing from an ordinary box in that its coils were wound flat on thin pieces of micanite.

*Coils and Condenser.*—The coils whose inductance were measured were as follows:

P, external diameter 33·46$^{\text{cm}}$, internal diameter 23·8$^{\text{cm}}$, was made of about 1200 turns of No. 16, B. and S. gauge single cotton-covered copper wire. Self-inductance as determined, ·5729 henry. Resistance, 36·3 ohms.

*C.* Same dimensions as P except depth. It consisted of 1747 turns of No. 22 B. and S. gauge single cotton-covered copper wire. Self-inductance found to be 1·3025 henry. Resistance, 78 ohms.

*S.* External diameter 23·5$^{\text{cms}}$, internal diameter 15$^{\text{cms}}$, depth about 3·5$^{\text{cms}}$. It consisted of 2082 turns of No. 22 B. and S. single cotton-covered copper wire. Resistance, about 69 ohms. Self-inductance found to be 1·0331 henrys.

*Condenser.*—A ⅛-microfarad mica condenser.

*Conditions of sensibility.*—The deflection of an electrodynamometer is proportional to the product of the currents flowing in the fixed and hanging coils multiplied by the cosine of the phase difference of the two currents. In most of these Rowland methods the adjustment consists in so altering non-inductive resistances in one or more branches of the bridge that there is a ninety degree phase difference between the currents in the fixed and hanging coils respectively. Evidently in order to secure maximum sensibility the currents through the dynamometer coils should be as heavy as possible, heating alone being the limit.

*Sources of Error.*—In work with alternating currents great care must be exercised that one part of the network does not exert an inductive action on another, e. g., that the coil whose inductance is being measured does not affect the hanging coil of the electrodynamometer. Induction was carefully guarded against by the arrangement and tested for by means of reversing switches. The electrostatic capacity of doubly wound coils and resistances has already been mentioned as well as the precautions taken to avoid it. In the experiments here described all the connections were made as short as possible and no wires were twisted. Heating of the resistances was avoided as much as possible and in the more accurate work the resistances of the several arms of the network were measured after adjustments on a Nalder standard "Post Office" box. All resistances are in International ohms.

## *Methods Used.*

### I.

*Method 25.*—The first method tried was that designated in Professor Rowland's article as number 25. It is an absolute method intended for the measurement of either self-induction or capacity, the value of which depends upon the square of the current frequency. It was given a thorough test by Dr. T. D. Penniman,* except in so far as his method of measuring the frequency was rough compared with that used in this investigation, and he ascribes the lack of uniformity of his results chiefly to a want of knowledge of the current period. It was therefore thought well to give the method a hasty trial in regard to the measurement of self-induction. In this method the hanging coil is shunted off the fixed coils circuit and the deflection with a non-inductive resistance in circuit with the hanging coil is made the same as that of an inductive resistance in circuit with the hanging coil. The method and connections are shown in figs. 2 and 3; F and H represent the fixed and hanging coils of the electrodynamometer; R, R′ and $r$, the total resistances of the three branches; L is the self-inductance of the coil to be measured, W is a reversing commutator. The formula for the method as deduced by Dr. Penniman is,

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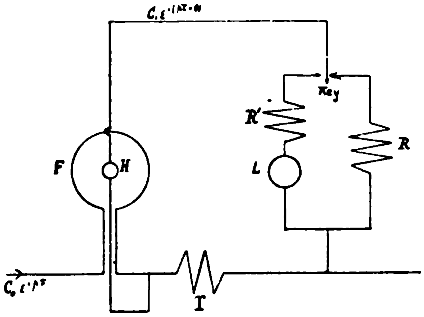

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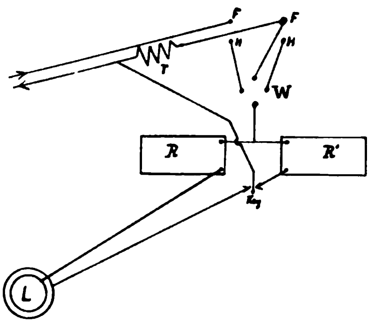

$$p^2 L^2 = (R'-R)\ (R+r)$$

where $p$ is equal to $2\pi$ multiplied by the current frequency.

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* This Journal, viii, p. 35, 1899.

This method did not prove satisfactory for measuring self-inductance. With care it is possible to obtain values which do not differ among themselves by more than 1 per cent. One drawback to the method is its lack of sensibility, that is, it is not usually possible to adjust the resistances closer than one part in three hundred. Again, since the electrodynamometer was very "dead beat" it required a certain small time to compare the deflections, to be sure not long, but enough for the current period to alter slightly unless special precautions were taken. A few determinations of the self-inductance of coils S and C are given. It will be noticed that the values are lower than those obtained later by a more accurate method. This is probably due to the use of ordinary resistance boxes possessing electrostatic capacity. This method was the first tried and is the only one in which such resistances were used.

TABLE I, Coil C.

| Zero. | Deflection. | R. | R′. | *r*. | *n*. | L. |
|---|---|---|---|---|---|---|
| 24·98 | 15·30 | 149·7 | 1513·7 | 4·017 | 57·567 | 1·266 henrys |
| “ | 15·49 | “ | 1531·7 | “ | 57·227 | 1·282 “ |
| 24.82 | 15·18 | “ | 1518·7 | “ | 57·453 | 1·271 “ |
| “ | 15·11 | “ | 1530·7 | “ | 57·510 | 1·275 “ |
| 24·77 | 12·70 | 199·7 | 1241·7 | “ | 57·453 | 1·276 “ |
| 24·73 | 12·62 | “ | 1238·7 | “ | 57·510 | 1·273 “ |
|  |  |  |  |  | Mean | 1·274 “ |

TABLE II. Coil S.

| Zero. | Deflection. | *r*. | R. | R′ | *n* (cycles). | L (henrys) |
|---|---|---|---|---|---|---|
| 240·0 | 158·2 | 4·017 | 141·5 | 1300·7 | 63·885 | 1·023 |
| “ | 158·5 | “ | “ | 1283·7 | 63·62 | 1·021 |
| “ | “ | “ | “ | 1283·7 | 63·329 | 1·020 |
| 239·2 | 301·0 | “ | “ | 1288·7 | 63·261 | 1·028 |
| “ | “ | “ | “ | 1281·7 | “ | 1·025 |
| 239·0 | 134·2 | “ | 191·5 | 1041·7 | 64·095 | 1·012 |
| “ | 134·8 | “ | “ | 1038·7 | 63·955 | 1·013 |
| 238·7 | 345·8 | “ | “ | 1036·7 | “ | 1·012 |
| “ | “ | “ | “ | 1038·7 | “ | 1·013 |
| 249·0 | 121·3 | “ | 241·5 | 920·7 | 64·095 | 1·014 |
| “ | “ | “ | “ | 922·7 | “ | 1·015 |
| 239·1 | 129·9 | “ | 291·5 | 850·7 | 64·167 | 1·009 |
| “ | “ | “ | “ | “ | 64·095 | 1·010 |
| 239·7 | “ | “ | 491·5 | 836·7 | 64·23 | 1·025 |
|  |  |  |  |  | Mean | 1·0171 henry |

## II.

*Method 14.*—The next method tested was that which in Professor Rowland's paper is number 14. It is an absolute method for measuring either self-inductance or capacity. It is a zero deflection method depending upon adjusting the resistances until there is a ninety degree difference in phase between the currents flowing in the fixed and hanging coils of the electrodynamometer. The method was devised and first used by Oberbeck,* later by Troje.† However, the frequency determination of both these investigators was quite crude and, as will be seen from the formula, the value of L or C varies as the square of the frequency. Diagrams of the method and connections are given in figs. 4 and 5. As before, F and H represent the fixed and hanging coils of the electrodynamometer; $R_{,}$, $R_{,,}$, $R'$, $R''$ and $r$ are the entire resistance of the several branches, L is the self-inductance of the coil to be measured, and $l$ that of the hanging coil of the electrodynamometer, W is a commutator for reversing the current through the hanging coil, S is a switch by means of which the current could be sent through a resistance X in value closely equal to the impedance of the network. The coil L, to avoid any possible effect on the rest of the network or hanging coil of the electrodynamometer, was placed some distance away usually on a level with the hanging and fixed coils and perpendicular to them.

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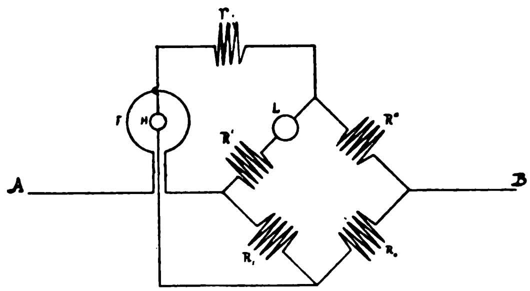

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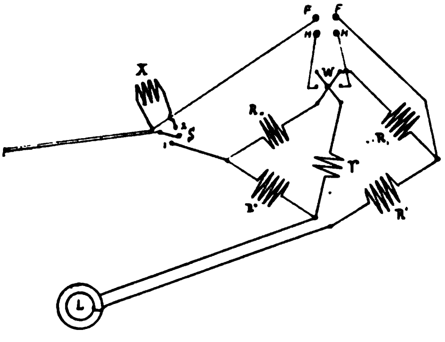

If now an alternating electromotive force be applied to the terminals A and B, we may express the currents in the fixed and hanging coils of the electrodynamometer by $C_0\epsilon^{ipt}$ and $C_1\epsilon^{i(pt+\phi)}$, $p$ being equal to $2\pi$ times the frequency. By the application of Kirchhoff's laws to the Wheatstone bridge using "generalized resistances," we obtain as the ratio of the current in the battery arm to the current the bridge arm,

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* Wied. Ann., xvii, p. 816, 1882. † Ibid., xvii, p. 501, 1882.

$$\frac{C_0}{C_{,}}\epsilon^{i\phi}=\frac{(r+ipl)\,(R_{,}+R+R'+R''+ipL)\,(R_{,,}+R'')\,(R_{,}+R'+ipL)}{R_{,}R''-R_{,,}R'-ipLR''}$$

Multiplying both sides of this expression by $C_{,}^2$, rationalizing, and equating the real parts we obtain,

$$\cos\phi=C_{,}^2\frac{[R_{,}R''-R_{,,}R']\,[r(R_{,}+R_{,,}+R'+R'')-p^2Ll+[R'+R_{,}]\,[R_{,,}+R'']}{[R_{,}R''-R_{,,}R']^2+p^2L^2R''^2}$$

$$C_{,}^2\frac{p^2LlR_{,,}\,(R_{,}+R_{,,}+R'+R'')-p^2L^2rR_{,,}-p^2L^2(R_{,,}+R'')R_{,,}}{R_{,}R''-R_{,,}R'+p^2L^2R''^2}$$

This expression must be equal to zero since we adjust the bridge until $\phi = 90°$, therefore $\cos\phi = 0$. Equating to zero and simplifying,

$$L^2+Ll\left\{\frac{(R''+R_{,,})\,(R_{,}+R_{,,}}{R_{,,}(r+R''+R_{,,})}\right\}=$$

$$\frac{R''R_{,}-R_{,,}R'}{p^2R_{,,}}\left\{\frac{r(R_{,}+R_{,,}+R'+R'')+(R'+R_{,})\,(R''+R_{,,})}{r+R''+R_{,,}}\right\}$$

This formula is somewhat simplified if $R_{,,}$ is chosen equal to $R.''$ However, for accurate work the equality must be exact. Since the self-inductance of the hanging coil of the Rowland electrodynamometer is so small, only ·0007 henry, the correction of L due to it is very small, in the case of coil C amounting to ·0004 henry.

In using the method the numerical work involved in the calculation of L is rendered somewhat easier if we write the formula,

$$L+sLl=t$$

when very approximately, since $l$ is so small,

$$L=t+\frac{S}{2}l$$

where

$$S=\frac{(R''+R_{,,})\,(R_{,}+R_{,,})}{r+R_{,,}+R''}$$

and,
$$t=\frac{1}{p^2}\left[R_{,}\frac{R''}{R_{,,}}-R'\right]\left[R'+R_{,}+\frac{r(R_{,,}+R'')}{r+R_{,,}+R''}\right]$$

This method was found to be excellent. It is very sensitive and very accurate provided certain precautions are taken. Some little difficulty was experienced at first from the fact that the values of the self-inductance of a coil measured on any one day, although agreeing pretty well among themselves,.

differed from those obtained at a different time. The cause of this variance proved to be the heating and consequent lack of knowledge of the resistances. In order to secure sensibility of the electrodynamometer it was the custom to make the current through the fixed and hanging coils quite heavy. Sometimes the current through the fixed coils was nearly $\frac{1}{10}$ ampere. This was unnecessarily large, as with a current of $\frac{1}{20}$ ampere it is easily possible to adjust the resistance to one part in fifteen hundred or two thousand. If we wish to make exact measurements of inductance, the method requires an accurate knowledge of the resistances. To take a specific example, if in the first determination in Table IV we increase R or R″ by 1/20 per cent, a change of −1/3 per cent is introduced in the value of L; similarly changing R or R′ by 1/20 per cent we alter L by +1/4 per cent. In regard to *r*, L varies only as the first power. Fortunately these errors in L introduced by variation of the resistance are not all of the same sign, and since the current through *r* must of necessity be quite small (about $\frac{1}{100}$ ampere) the currents through R + R, and R′ + R″ are nearly equal. Hence if we assume an increase of all the resistances of 1/20 per cent, the value of L is increased by about one part in one thousand three hundred. Therefore, to obtain the best results with this method we must measure the resistances carefully and avoid much heatings. To avoid heating of the resistances the following plan of taking readings was adopted. The bridge was first adjusted, this being done by altering R′ and R, until on reversing the current through the hanging coil of the electrodynamometer there was zero deflection indicating a ninety degree phase difference between the fixed and suspended coils. By means of the switch S (vide fig. 5) the current was turned through the resistance X, made closely equal to the impedance of the network. This was done to avoid change in the frequency. After a considerable interval, sufficient to avoid the effect of any slight heating in the preliminary adjustment, the current was again switched through the network and R, remaining the same, R′ readjusted to give zero deflection, the exact time of adjustment being noted in the chronograph sheet. This adjustment when made would usually hold good for several minutes. However, it was not usually necessary to run the current through the network longer than twenty or thirty seconds. This process was repeated a number of times with longer or shorter intervals and then the resistances R′ and R, measured. The other arms of the bridge were measured once or twice during the evening; this time was chosen as being free from various disturbances. Generally for several successive observations the same value of R′ would give zero deflection, R, remaining the same. The mean of the frequencies measured for the several observations was taken as being nearest correct.

If, however, R′ had to be altered, the observations were regarded as separate and so worked out.

It was not the purpose of the authors to measure inductance to any great degree of accuracy, but to indicate the possibilities of the methods. Resistances were measured only to about two or three parts in ten thousand on the post office box, which had a considerable temperature correction. Still it will be seen that the determinations of L, except those of coil P, differ from the mean by less than 3/10 per cent.

The measurements of coil P were among the first made with this method, and the resistances were not measured with as much care as in the case of the other coils.

TABLE III.

Oct. 24, 1903.

| $R_,$ | $R''$ | $r$ | $R_,$ | $R'$ | $n$ | L |
|---|---|---|---|---|---|---|
| 103·75 | 103·67 | 425·06 | 900·76 | 870·9 | 65·644 | ·5722 henry |
| “ | “ | “ | 900·76 | 870·9 | 65·614 | ·5725 “ |
| “ | “ | “ | 948·23 | 919·72 | 65·763 | ·5715 “ |
| “ | “ | “ | 989·3 | 961·7 | 65·763 | ·5737 “ |
| “ | “ | “ | 900·76 | 870·94 | 65·614 | ·5723 “ |
| “ | “ | “ | 948·23 | 918·67 | 65·614 | ·5733 “ |
| “ | “ | “ | 989·3 | 961·7 | 65·614 | ·5749 “ |
|  |  |  |  |  | Mean | ·57291 “ |

TABLE IV, Coil C.

Dec. 10, 1903.

| Temp | $R_,$ | $R''$ | $r$ | $R'$ | $R'$ | $n$ | L (henrys) |
|---|---|---|---|---|---|---|---|
| 16°·3C. | 99·907 | 99·78 | 968·8 | 1199·86 | 1088·6 | 63·288 | 1·3044 |

After the elapse of some minutes.

| Temp | $R_,$ | $R''$ | $r$ | $R'$ | $R'$ | $n$ | L (henrys) |
|---|---|---|---|---|---|---|---|
| “ | “ | “ | “ | 1199·86 | 1088·6 | 63·288 | 1·3044 |

Dec. 13, 1903.

| Temp | $R_,$ | $R''$ | $r$ | $R'$ | $R'$ | $n$ | L (henrys) |
|---|---|---|---|---|---|---|---|
| 15°·0 | 99·94 | 99·42 | 968·9 | 1200·47 | 1088·0 | 62·366 | 1·3055 |
| “ | “ | “ | “ | “ | “ | 62·446 | 1·3008 |
| “ | “ | “ | “ | “ | “ | 62·259 | 1·3047 |
| “ | “ | “ | “ | “ | “ | 62·206 | 1·3058 |
|  |  |  |  |  |  | Mean | 1·30257 |

TABLE V, Coil S.

Nov. 13, 1903.

| $R_,$ | $R''$ | $r$ | $R_,$ | $R'$ | $n$ | L (henrys) |
|---|---|---|---|---|---|---|
| 100·0 | 100·0 | 425·06 | 1815·5 | 1767·2 | 65·393 | 1·0309 |
| “ | “ | “ | “ | 1766·67 | 65·393 | 1·0366 |
| “ | “ | “ | 1862·9 | 1815·5 | 65·688 | 1·0303 |
| “ | “ | “ | 1904·0 | 1856·96 | 66·091 | 1·0311 |
| “ | “ | “ | 1904·0 | 1856·96 | 65·763 | 1·0353 |
|  |  |  |  |  | Mean | 1·0329 |

TABLE VI, Coil S.

May 13, 1904.

| $R_{\prime\prime}$ | $R''$ | $r$ | $R_{\prime}$ | $R'$ | $n$ | L | |
|---|---|---|---|---|---|---|---|
| 100·16 | 99·42 | 1020·2 | 1816·9 | 1734·0 | 78·121 | 1·0345 | henrys |
| " | " | " | " | 1734·5 | 78·303 | 1·0359 | " |
| " | " | " | " | 1760·6 | 61·797 | 1·0307 | " |
| " | " | " | " | 1734·5 | 78·278 | 1·0325 | " |
| " | " | " | 1905·3 | 1819·3 | 81·410 | 1·0330 | " |
| " | " | " | " | 1818·3 | 81·700 | 1·0365 | " |
| " | " | " | " | 1848·8 | 62·604 | 1·0354 | " |
| " | " | " | 1616·0 | 1529·6 | 76·456 | 1·0333 | " |
| " | " | " | " | 1528·3 | 76·068 | 1·0294 | " |
| " | " | " | " | 1530·1 | 76·428 | 1·0299 | " |
| | | | | | Mean | 1·02331 | " |

## III.

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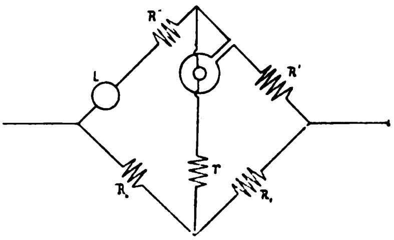

*Method 13.*—Method 13 was next tried. This is also an absolute method for measuring either self-inductance or capacity. It is a zero deflection method depending on a ninety degree phase difference just as in method 14. In fact it differs from that method only in that the fixed coils of the electrodynamometer are no longer in the battery arm of the bridge. The connections are shown in the diagram. Neglecting the self-inductance of the fixed and hanging coils of the electrodynamometer, the formula for the method may be deduced as follows. Proceeding as before, we find the ratio of the current in the fixed and hanging coils

$$\frac{C_2}{C_6}\epsilon^{i(\phi_2-\phi_6)} = \frac{r(R_{\prime\prime}+R_{\prime})+R_{\prime}(R_{\prime\prime}+R''+ipL)}{R'R_{\prime\prime}-R_{\prime}R''-ipR_{\prime}L}$$

Rationalizing the fraction, and taking the real parts, we have for zero deflection;

$$p^2L^2 = \frac{\{R'R_{\prime\prime}-R_{\prime}R''\}\ \{r(R_{\prime}+R_{\prime\prime})+R_{\prime}(R_{\prime\prime}+R'')\}}{R_{\prime}^2}$$

We should expect this method not to be as sensitive as Method 14, for the reason that we must in general have a smaller current in the fixed coils of the dynamometer. Moreover, since the formula is similar in character to that of Method 14, we would look for the value of L to be affected in the same way by a slight heating of one or more of the resistances. {The formula for Method 14, neglecting hanging coil correction is

$$p^2L^2=\frac{[R_{,}R''-R'R_{,,}]\,[r(R'+R_{,}+R_{,,}+R'')+(R'+R_{,})(R''+R_{,,})]}{R(r+R''+R)}\Big\}$$

The method was set up and some determinations made of the inductance of coil C. The method proved much less sensitive than Method 14, under comparable conditions only about one-half. By sensitive is meant the degree of accuracy to which it is possible to change the resistances, in securing adjustment.

It is to be noted that the formula as given neglects the self-inductance of the fixed and hanging coils of the electrodynamometer. The exact formula is not difficult to work out, but the method is hardly sensitive enough to justify the trouble.

A few measurements of the inductance of coil C were made with some care. The values obtained were low compared with those previously obtained, as will be seen from the following example.

$R_{,,}=1201{\cdot}7$ ohms $R''=1560{\cdot}6$ ohms $r=309{\cdot}91$ ohms
$R_{,}=\ \ 99{\cdot}89$ " $R'=\ 133{\cdot}33$ " $n=\ 69{\cdot}153$ "
$L=1{\cdot}1483$ henrys

## IV.

*Methods 1, 2, 3, etc.*—Attention was not turned to the first six methods given in Professor Rowland's paper, which are for the comparison of self-inductance with capacity. They are all zero deflection methods depending on a ninety degree phase difference. As will be seen from the formulæ, the value of $\frac{L}{C}$ is independent of the frequency. Two of these methods have already been used. Method 6 was studied by Mr. Penniman but did not yield favorable results. Method 3 was employed by Mr. Potts in the course of some work on electric absorption, and was found very satisfactory. The diagrams and formulæ for the methods are as follows. The method of deducing the formulæ is the same as that followed in the preceding cases.

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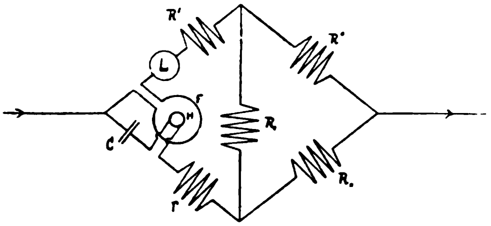

*Method 1.*—See fig. 7.

$$\frac{L}{C}=\frac{[r(R_{,}+R'')+R_{,,}(r+R_{,})]\,[R'(R_{,}+R_{,,})+R''\,(R_{,}+R')]}{(R_{,}+R''+R_{,,})^2}$$

The trouble with this method was its lack of sensibility. Various values of resistances and coils were tried, but with the arrangement, which was as sensitive as possible, the resistances could not be adjusted closer than 1/5 per cent. This also when the maximum current was flowing through the network. It will be noted that the formula is quite similar to that of Method 14, so we should expect the value of $\frac{L}{C}$ to be affected in the same way as was L by a slight change in one or more of the resistances. The values of the resistances which seemed to give the most sensitive arrangement when coil P was compared with a ⅛-microfarad mica condenser were,

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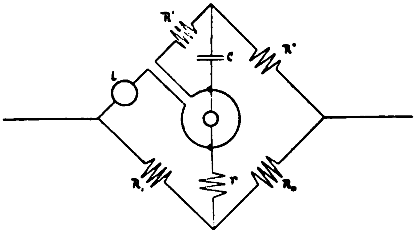
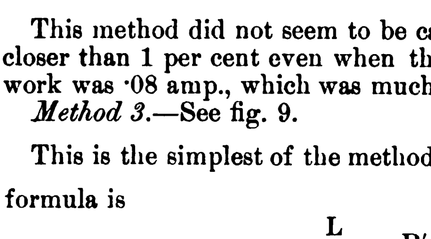


R' = 336 ohms
R, = 1200 ohms
R'' = 100 ohms = R
$r$ = 3900 ohms

*Method 2.*—See fig. 8. When L = ·570 and C = ⅛-microfarad. The values of the resistances which seemed to give the most sensitive arrangement were,

R'' = R,, = 100 ohms
R, = 1600 ohms
R' = about 1600 ohms

9



This method did not seem to be capable of adjustment much closer than 1 per cent even when the current through the network was ·08 amp., which was much too large to avoid heating.

*Method 3.*—See fig. 9.

This is the simplest of the methods for determining $\frac{L}{C}$. The formula is

$$\frac{L}{C}=rR'.$$

As has already been stated, this method has been used with success. The present writers set up the method and compared coil P with the $\frac{1}{3}$-microfarad condenser. The method is very sensitive. With $r = 3070$ ohms and $R = 485$ ohms, a change of two ohms in $r$ caused a change of $1^{mm}$ in the deflection of the electrodynamometer. Determinations of the ratio $\frac{L}{C}$ were not made for the reason that if we wish accurate results it is necessary to measure the absorption resistance of the condenser. This should be done at each determination of $\frac{L}{C}$, as the absorption has been found to vary greatly both with the temperature and the frequency.

The diagrams and formulæ for Methods 4 and 5 are given: also the values of the resistances of the arms which seemed to give the most sensitive arrangement. As before, coil P, was compared with the $\frac{1}{3}$-microfarad condenser.

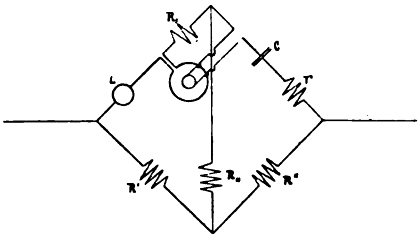
*Method 4.*—See fig. 10.

$$\frac{L}{C} = \frac{\{R'(r+R_{,,})+R''(R'+R_{,,})\}\ \{R'(R''+R_{,,})+R''(R_{,}+R'')\}}{R'R''}$$

As adjusted,

$R_{,,} =$ 88·54 ohms
$R' =$ 1021·8 ohms
$R'' =$ 99·5 "
$r =$ 492·0 "
$R_{,} =$ 317·5 "

10



With $C = {\cdot}086$ ampere, a change of 4·4 ohms in $r$ is barely detectable and a change of ten ohms in $R'$ produces only $2^{mm}$ deflection as measured on the scale of the electrodynamometer.

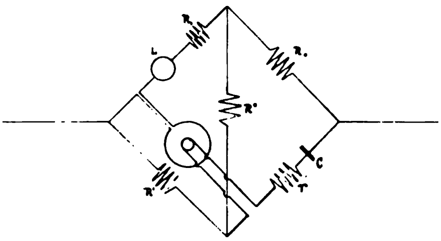
*Method 5.*—See fig. 11.

$$\frac{L}{C} = \frac{[R_{,}(R''+R_{,,})+R_{,,}(R''+R')]\ [R'(R''+R_{,,})+r(R'+R'')]}{(R'+R'')\ (R''+R_{,,})}$$

As adjusted,

$R_{,,} =$ 100 ohms
$R'' =$ 88·5 "
$R_{,} =$ 1041·5 "
$R_{,} =$ 317·5 "
$r =$ 1678·4 "

11



This method is somewhat more sensitive than Method 4, however, it is not possible to adjust closer than one part in five hundred.

## V.

### *Methods 7, 8, 9, 10, 11, and 12.*

Of the remaining zero-deflection methods which depend on a ninety degree phase difference, little needs to be said. Methods 7 and 8 are for determining $\frac{L}{C}$ but involve mutual inductance and are intended to be used with doubly wound coils. For accuracy greater than one per cent such coils are very undesirable on account of the electrostatic capacity, and should not be used. Methods 9 and 10 are for comparing mutual inductance with capacity. Method 12 was investigated by Mr. Penniman.

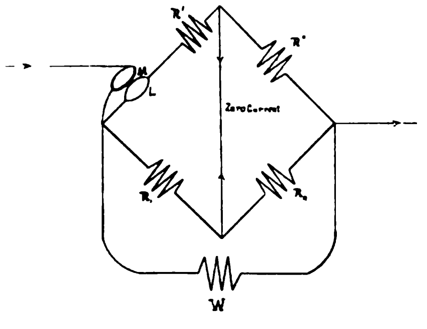
## VI.

### *Methods 15–24.*

The rest of the methods require at least two adjustments; first, the Wheatstone bridge must be balanced with direct currents, then adjustment made with alternating current so that the current through the bridge arm is zero. Of these methods, 15 and 16 are for comparing two inductances, two capacities or inductance with capacity. However, Method 15 requires after balancing the bridge with direct currents two simultaneous adjustments with alternating current; and Method 16 requires many resistances of known ratio. Method 17 is for the measurement of $\frac{L}{M}$, but as Professor Rowland points out: "It is difficult to apply, as two resistances must be adjusted and the adjustment will only hold while the current period remains constant." These methods did not seem to be worthy of trial.

Method 18 is for the determination of $\frac{L}{M}$ where L and M belong to the same coil. This method is simpler than most of the others and seemed rather more promising, so it was given a trial. The diagram of the method is shown in fig. 12.

12



The bridge is first balanced with direct currents giving

$$R'R_{''} = R'R''.$$

Then with alternating current W is adjusted until there is zero current through the bridge arm, as shown by an electrodynamometer or telephone. When this is the case the mutual inductance completely counterbalances the self-inductance, so that the currents and electromotive forces are in phase in each arm of the bridge. Representing current through R′ by I′, etc.,

$$R_{,}I_{,} = R'I' + ipLI' - ipM\,(I' + I_{,} + I_w)$$

also

$$R_{,}I_{,} = R'I'$$

and

$$\frac{I'}{I_w} = \frac{W}{R' + R''}$$

$$\therefore \quad \frac{pM\,(I' + I_{,} + I_w)}{I'} = pL$$

Hence

$$\frac{L}{M} = 1 + \frac{R'}{R_{,}} + \frac{R' + R''}{W}$$

The method was set up so that by means of switches the resistance W could be replaced by the battery, and the electrodynamometer by the galvanometer. The method proved very unsatisfactory. Using the electrodynamometer in the bridge arm, its coils being connected in series, W could not be adjusted closer than three per cent. Different values of the resistance were tried but the result was about the same. The electrodynamometer was then replaced by a telephone. It was then possible to adjust to about two per cent but the noise of the dynamo interfered somewhat with the use of the telephone. The conclusion was that the method is not sufficiently sensitive to be of value.

Method 19 is also intended for the measurement of $\frac{L}{M}$ but involves the use of a doubly wound coil.

Methods 20 and 21 require a specially doubly wound inductance coil. They were not thought sufficiently promising to merit the construction of such a coil.

Method 22 is Carey Foster's method adapted to alternating currents. This method was rather thoroughly investigated by Heydweiller.*

Method 23 requires two simultaneous adjustments with alternating currents, and Method 24 is only of special use in comparing two doubly wound coils.

## *Summary.*

With the exception of Methods 14, 3 and 25 the Rowland methods tested are of little value, their chief defect being a lack of sensibility. Method 14, or more properly, the Oberdeck method, is without doubt the best method that we have for the absolute measurement of self-inductance in terms of resistance. It is easy to apply and if proper care be exercised results should not differ from the mean by more than 2/10 per cent. Greater accuracy than this is undoubtedly attainable and ought not to be a matter of any great difficulty, for in the work here described the frequency determination could have been improved and the resistances much more accurately measured. Method 25 is better than the Rayleigh method as ordinarily used, is very easy to work and has a very simple formula, involving little calculation. Its accuracy is probably limited to about one per cent. Method 3 for comparing self-inductance with capacity is very sensitive and was found by Dr. Potts to be very satisfactory.

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* Wied. Ann., liii, p. 499, 1894.

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## Art. X. — *Climatic Features in the Land Surface;* by Albrecht Penck.

The surface of the land is composed of slopes which are for the most part gentle. Steep cliffs and overhanging forms are exceptional and insignificant features; where they occur, they are soon destroyed. Their fragments fall and slide and finally creep down; thus all cliffs and overhanging forms are transformed in the course of time into slopes and finally into long grades. It is important to see that this process can be accomplished simply by the force of gravity, helped by the action of weathering, but without the interference of water. The grading of the land surface is therefore a planetary process which will occur on every planet whose surface is liable to weathering as a result of changes of the surface temperature. The slopes formed by weathering are normal to the direction of those cliffs from which they originated, and if there was no stream or wave action, no glacial or wind action on the earth, the direction of slopes would be determined chiefly by the direction of the cliffs formed by earth movements, and we should observe in all slopes of the surface of the earth the directions of crustal and volcanic movements.

But the direction of the slopes on the land surface reveal other features, and a study of the processes going on on the land surface shows us that the origin of its slopes is above all connected with atmospheric action. Running water produces long and extensive slopes by its erosive and constructive force; it is enabled to transform slopes caused by crustal movements into others which show a perfect adjustment to the material of the earth's crust; and finally it wears the land down to gently sloping surfaces of the highest resistance. Running water also deposits material in the form of gently sloping plains, which extend very far. The action of running water is therefore both a degrading and an aggrading one, and the grades which it forms show a systematic arrangement; they slope down in the direction in which the water moves, mostly towards the sea; on one quarter of the land surface, however, towards the interior of the continent, where the running water is evaporated; and exceptionally in several regions composed of soluble rocks, to those points where water enters the rock to follow there a subterranean course. The latter case is a rather unusual one; it is connected with the very remarkable forms of the Karst phenomenon, which, however, are only of limited extent.

Glacial action also produces slopes, either due to erosion or to accumulation, but these slopes do not show such a systematic arrangement as the grades of fluviatile origin. Glacial action does not impose on the land the continuity of its surface slopes as running water does; it produces irregularities in its bed which not only show continuous slopes but often opposite and reversed slopes. Wind also produces slopes, but their arrangement is still more irregular than those of a glacier bed. There is a sharp limit between the regions of glacial erosion and of glacial deposition: the forms of eolian erosion and eolian deposition also occur in close proximity; wind does not transport so continually nor so far as running water and glaciers do; its action is more brief and unsteady. Thus, the arrangement of the slopes of the land surface permits us to recognize fluviatile, glacial and eolian forms.

Now the action of running water and of glaciers and the display of eolian forces depend on climate; rivers exist only where a part of the rain runs off superficially on the land; their morphological action depends, therefore, on the amount of run-off, which is consequently a geomorphological factor of great importance. Glaciers are formed only where the amount of snowy precipitation surpasses that amount which can be melted away by the action of the sun. Wind action finally becomes very visible, and is exclusively performed where neither water nor ice action occur. We see, therefore, that the differences between precipitation and evaporation on one side and between snowfall and ablation on the other, determine the surface features of the land, and hence we can recognize in the surface features of the land certain features of its climate in the same way as in its covering with vegetation.

The display of river action does not depend alone on climatic conditions. River movement is only possible where there is a slope on which the rivers can flow. Only their existence is due to climate, while the display of their force depends on differences of elevation, and their action consists in the degradation of existing heights. Glaciers do not necessarily presuppose elevations; they can be formed also on low grounds, if the climatic conditions of their formation are given. If more snow falls on a plain than can be melted away, it accumulates and will finally form an ice-cap which radiates from the plain; if here the accumulation reaches a great thickness, it can then overcome finally by its surface slope existing inequalities of its bed, as is clearly shown by the glaciation of North America during the Great Ice Age, which partly radiated from the low grounds west of Hudson Bay and overflowed in the east the mountains of New England. Whilst river action consists in the destruction of given inequalities of the earth's surface, glacier action can create new inequalities by the erosion of the central floor of an ice-cap formed at a low level and the deposition of the eroded material in higher levels around this center. The same can be said of eolian action. Wind can blow sand and dust from lower levels to higher ones, and if its action were long continued, it could lower the surface of vast tracts of land and raise the surface of others; the lowered surfaces could lie below the raised ones.

In order to understand more thoroughly the difference of river action on the one hand and of glacial and wind action on the other, let us consider their probable final results. In the course of time the rivers will totally degrade the continents to vast peneplains and will extend them seaward by the accumulation of river plains; then they will have no action. A polar ice-cap will attack its floor if the slope of its surface is greater than the reversed slopes of its floor, and around this eroded area accumulation will go on. The difference of height between the central eroded area and the peripheral belt of deposition will be theoretically the larger the greater the thickness of the ice-cap, and it is theoretically possible that a very thick and moving polar ice-cap could finally excavate a deep basin in the polar region which would be surrounded by a high morainic belt. These processes would not only be accomplished on the land, but the ice-cap could also act on those parts of the sea-bottom which are not deep enough to make the ice float; and the morainic belt could therefore be accumulated as well on the land as on the bottom of the sea. But where the bottom of the sea becomes too deep, the ice-cap would break into pieces which would float away as icebergs and distribute the morainic material over vast areas of the sea-bottom. Let us assume that wind action operates unhindered by vegetation and the action of running water. Then the constant trade-winds would continually carry with them sand and dust which were accumulated in an equatorial belt, where the trade winds cease, and this action would be continued as long as the area eroded by the wind were not invaded by the sea. It could be eroded beneath sea-level as long as there were coast regions protecting it as natural levees against the waters of the ocean. Wind action does not necessarily stop at sea-level; the depressed areas of the land clearly show us that it is continued farther down. If, however, those natural levees are destroyed, vast regions denuded by wind action below the sea-level would suddenly be inundated and converted into seas. The material transported by the wind would be deposited not only on the land, but also in the neighboring seas, and an increase of the equatorial land area would be the consequence of continued wind action. Thus, by mere eolian activity, the distribution of water and land could be altered.

The effects of polar ice-caps and continual wind action would consist in the movement of material from higher latitudes into lower ones, and the areas of erosion and deposition would show a zonal arrangement, whilst running water transports from higher regions to lower ones, and the corresponding areas of its action are controlled by the existing distribution of water and land. Glaciers and winds accomplish an important transportation of material from lower to higher positions. What we see in river action consists only of a downward transportation, and it generally ceases at sea-level; it can only be exercised below it in countries which extend for other reasons below this level, as for example, in the border regions north of the Caspian sea; whilst glaciers and winds could make vast depressions of the land beneath the sea-level.

These differences between visible river action on the one hand and glacial action on the other seem to be at first sight very strange, but a closer inspection shows that when speaking of river action we generally have in mind the processes which go on above the level of the river. We generally do not think of the processes performed in the river bed itself, for they are hidden under the water. But the study of river beds reveals that here much material is carried upwards and that the depth of the rivers is not at all limited by the sea-level. All river beds which reach the sea lie below the level of the sea near their mouths, and their bottoms extend the deeper and the farther below the sea-level the greater their volume. On the other hand, if we speak of glacial or wind action we have always in mind the processes going on in the beds of these moving fluids. These beds are of far larger extent than those of rivers, and therefore the action performed in them is far more conspicuous. The action of rivers in their beds gives origin to all those subærial processes which widen the vertical trench of a river into a valley and produce slopes towards the river. These subærial processes are the more important for the development of the earth's surface-features; they perform what we usually call river action, but they are not controlled by the movement of water, and belong to that class of phenomena which are dependent on the action of gravity.

The actual surface features of the land differ from those which are produced by continuous river, glacial and wind action. The land is not leveled down to a peneplain, no mountainous moraines are formed around vast depressions, and there is no equatorial belt of wind deposition between regions where deflation produced lowlands. We meet with elevations which are still in the state of being degraded and which are not made by glacial or eolian accumulation. The existence of those elevations reveals the existence of forces which counteract the atmospheric agencies, and which have counteracted them the more, the greater the difference between the actual distribution of heights and the ideal ultimate effect of those agencies. In countries with dominant river action the existing elevations are differences between the effects of earth movements and the consequent degradation by river action. Their height is therefore determined by the intensity of crustal movement and by the time that has since elapsed. There are young mountains, attacked only along certain lines by water, which has only made an approach toward destroying the fortress; there are mature mountains which have already lost their unstable annexes and are formed by rocks of greatest resistance; there are old mountains degraded as far as possible, no longer forming elevations.

Young, mature and old mountains show very different structures, and we cannot, therefore, connect the idea of a certain class of crustal movement with mountain-making. Mountains are caused by all crustal and volcanic movements which are directed upward, either totally or as a component. But whatever the character of these movements is and however complicated they may be, they only exceptionally interrupt the slopes of fluviatile degradation. This is shown by the facts that even in the regions of most recent elevations the continuity of the fluviatile slopes or grades is only exceptionally interrupted, and nearly all of these interruptions occur in volcanic regions, where sudden outbursts take place. The intensity of crustal movement, therefore, is not so great that it can disturb the continuity of fluviatile slopes; crustal movement can disturb a former arrangement of slopes, it can produce new slopes, but by their erosion and accumulation rivers maintain the continuity of slopes.

In desert regions crustal movements are able to interrupt slopes, for they are not counteracted by running water. It is in the deserts of the Far West where we see the best samples of recent faults; they cut through alluvial fans and form well-marked steps in regions of deposition and erosion. It is also in the deserts where we meet with such an arrangement of mountains that closed basins are formed. These closed basins came into existence because the grading river action was absent, and though formed by crustal movement, they are also climatic features of the earth's surface, for they are only produced under certain climatic conditions, namely, in regions where the amount of evaporation surpasses that of precipitation.

We see on the earth's surface not only the features of the present climate but also those of a past climate. Very extended areas, formerly covered by ice, are now exposed to river action. The basins formed by the meeting of normal slopes and those reversed slopes which originated under the ice, are filled with water and form lakes; the river action has not reached a normal slope; waterfalls interrupt their courses. These lakes and waterfalls are indications of extreme youth of river action over large areas, and at the same time they are as significant morphological evidences of a recent climatic change as moraines and rock striations are in the geological sense. In mountain regions, as for example in the Alps, the lakes occupy valleys which have the arrangement of river valleys; they are subordinate to an older topography, formed by fluvial action, and we can recognize in the valleys of the Alps not only one climatic change, but a succession of those changes. In the lowlands of the north, however, it is nearly impossible to trace the features of an older topography under the glacial one. This, however, does not show those signs of antiquity which we might expect to find in regions of continual glaciation. Hence we must infer that the glacial features of other northern lowlands are also superposed on an older topography which has been destroyed in its characteristic features. We see on the border regions of the old glaciations moraines which have totally lost their morainic forms, and already possess the surface features of a mature fluviatile topography. These surface features have long ago led to the conclusion that we have to deal here with older moraines, which indicate an older climatic change. Thus regions of river degradation indicate climatic change by their composition as well as glaciated regions indicate such change by their forms.

We meet with proofs of climatic changes, also in desert regions. Investigations of American geologists, especially of Gilbert and Russell, have shown that the region of Great Salt Lake was once occupied by a far larger freshwater lake, the shore lines of which can be easily followed and the outlet of which can be recognized in a side valley of Snake river. We can trace in the Sahara very extended river valleys from the Highland of Ahaggar down to the region of the south Algerian Shotts. These valleys cannot be compared with those short wadies in which the water of cloudbursts rushes down. They indicate a former moister climate; the desert with its surface features extends here over a region of former water action in the same way as, farther north, river action is now displayed on a surface formerly covered by glaciers.

In the interior of two continents we finally meet with surface features which might be taken for morphological indications of a change of desert climate into a moister one. Three large lake basins interrupt the general grades of the head waters of the principal African rivers. In the region of the Zambesi river we find the very deep Lake Nyanza, in the catchment basin of the Congo the likewise deep lake Tanganyika, and along the upper branches of the Nile the Victoria Nyanza. There are good evidences that the two first named lakes occupy depressions formed by crustal movement. Now we have seen that generally crustal movements, however profound they may be, do not interrupt the formation of slopes of degradation. Why did such interruption occur in central Africa? In order to give an answer, let us consider how the formation of isolated basins by crustal movement is hindered in the regions of fluviatile drainage. A tract of land, sinking down, is filled up by sediment during its subsidence; thus the rivers maintain their slopes and the formation of closed basins is counteracted. Elevations occurring in river basins are often cut through by rivers during their elevation, and then they will not transform neighboring regions into closed basins. The formation of those basins by crustal movement will occur only when the rivers in the disturbed regions are too feeble to fill up the sinking regions and to cut through the rising chasms. The central African great lakes are located in the neighborhood of insignificant river action. East of them extend the dry plateaus of German East Africa. Here crustal movement has produced many closed basins called Gräben (tectonic troughs) by Suess. Many of these Gräben are empty, or filled only at their bottoms with soda-lakes; others are nearly filled, as for example, Lake Rudolph. A slight climatic change would fill the basin of this lake so that its waters would overflow in wet years. This is the case with Lake Tanganyika. Its outlet, the Lukuga, flows only in wet years; in dry years the great lake is without outlet. A stronger climatic change would transform Lake Rudolph into a normal freshwater lake with permanent outflow. This type of lake is represented in the neighborhood by the Victoria Nyanza, by the Albert and Albert Edward Nyanza, and farther south by Lake Nyassa. We can understand best the existence of the large freshwater lakes of east equatorial Africa by assuming that their water drowns basins formed in a dry climate, such as prevails farther east. It is very significant that these great lakes occur in a region of transition between the dry and the wet tropical climate, a region which would be affected very much by climatic changes. The same is true for Lake Baikal in eastern Siberia. It belongs to a zone of great inland lakes at the northern border region of the central Asiatic deserts. Three of these lakes have salt water; two of them are so large that they are called erroneously seas, namely Lake Caspian and Lake Aral; the third is the shallow lake Balkash. An increase of precipitation over Russia would cause a raising of the level of Lake Caspian and an extension of its surface, and if on this larger surface evaporation would not balance the increased inflow, and establish thus a new equilibrium, then the lake will overflow in the Manich valley and would be changed in the course of time into a freshwater lake. On the other hand, if the desert region of Mongolia should extend, the principal affluent of Lake Baikal would become smaller, and a moment would arrive when the quantity of water running into Lake Baikal would be totally balanced by the evaporation going on there. Then this lake would lose its outlet, and the salts brought by its affluent would gather in its basin, and it would be transformed into a salt lake. Such rather light climatic changes would transform the salt lakes of the northern border regions of the central Asiatic deserts into freshwater lakes, or the large freshwater lake into a salt lake. We can understand best the existence of these lakes by the working hypothesis that their basins were formed originally in a dry climate, where river action could not neutralize transformation by crustal movement, and that they thence were more or less filled with water, according to the actual climate of their region. In this way we are disposed to recognize also in the great freshwater lakes in the interior of some continents morphological witnesses of climatic changes.

If we now look over the whole set of evidence, we see morphological traces of glacial action in countries which are now drained and shaped by running water, and recognize in mountain chains, as for example the Alps, traces of river action preceding this glacial action. We follow traces of extended river action into the desert, and we find forms which were probably produced in a dry climate, with no run-off, in regions which are now subject to river action. The climatic features of the land surface indicate that climatic changes are not only in one direction; we cannot say that the climate of the land is becoming dryer and dryer, or less and less glacial; they reveal continued climatic oscillations. These climatic oscillations are different in the different zones of the earth. We have to deal with oscillations between glacial and pluvial climate, and with oscillations between pluvial and desert climate. It is now the question, how these different oscillations were connected with one another, if there is a contemporaneity between them; and which changes were contemporaneous, those of glacial to pluvial climate with those of pluvial to desert climate, or *vice versa.* The evaporation of the deserts of the Far West has given one answer: it was there shown that the glaciers existed at the same time that the climate was moister. From this we can infer that one of the climatic oscillations indicated by the surface features of the earth consisted in a movement of the climatic zones from the pole towards the equator and back again. If this inference is right, we must find on the equatorial belt of the great desert regions of the world traces of an old desert climate, where now a pluvial climate dominates. It is possible that the great central African lakes point in this direction; perhaps Lake Titicaca indicates by its content of rather fresh water that once the deserts of South America extended farther towards the equator, and perhaps the lakes of the plateau of Mexico point to the same relation with the deserts of North America, whilst Lake Baikal would indicate an opposite movement of the climatic zones from the equator towards the poles, which cannot have been contemporaneous.

There is one fact known from the Arctic regions which is in harmony with a migration of the climatic zones of the earth. Neither the American expeditions which have explored the neighborhood of Smith Sound, nor the Norwegian expedition which studied the archipelago lying farther west, succeeded in finding the traces of a former greater extent of the glaciers, which are so abundant farther south. At first sight this fact appears rather strange, but it can be understood in connection with the others. It shows that during the glacial period glacial conditions did not extend farther towards the pole into those regions where now the Arctic climate, on account of its dryness, is not very favorable to the formation of glaciers. The great glaciations of the northern hemisphere were not extensions of a polar ice-cap; they were confined to the vicinity of the Arctic circle, and they surrounded, as far as we can see, a region of an Arctic desert climate similar to the existing one. This fact would be consistent with an equatorial movement of the climatic zones of the earth.

If there are oscillations in the situation of the climatic belts of the earth, it must be asked if they are connected with the disappearance of existing climatic zones and the appearance of new ones. For this reason the equatorial and polar regions attract particular interest; it can be imagined that in times of an equatorial movement of the climatic belts some features of the equatorial climate would totally disappear, and new climatic conditions could come into existence in the polar regions. The reverse would occur in times of a polar movement of the climatic zones. There is also much interest in the study of all border regions of climatic belts, for every movement of climatic zones of the earth would here produce changes.

The very extended border region of the glacial and the pluvial climate has afforded a splendid occasion for the study of past climatic changes; the climatic history of the great Ice Age could here be determined by a careful study of the corresponding deposits, and newer researches have utilized to great advantage the glacial forms in determining the glacial climate. The forms of the earth's surface indicate climatic changes also in other regions of the earth, and further research will help us to establish the general rule of all their climatic oscillations, and we shall understand them the better the greater our knowledge of the surface forms.

The forms of the earth's surface are very complex things. In the beginning of geological research it was generally maintained that every rock had its peculiar forms, and still to-day some text-books contain pictures of granite or sandstone mountains. Later, it was believed that every kind of structure of the earth's crust assumed its own surface features, and structural geology was regarded as the very content of geomorphology. Later still was recognized the importance of the different exterior processes which shape the earth's surface, and there are still many differences of opinion as to their effects. It is only recently that the full importance of time has been observed for the development of surface features. After having seen how different the forms are which come into existence in a natural sequence under the control of a certain process, as shown by the geographical cycle, we can fully appreciate the differences of fluviatile, glacial and desert forms, and we shall have thus gained the possibility of such a close examination of forms that we can read their history.

This study of erosional forms can be supplemented by that of corresponding deposits. We now easily separate river deposits from moraines, which in the beginning of scientific research have been taken for the results of large floods. It is also possible now to distinguish the deposits of different phases of a geographical cycle from one another, and the variegated or impoverished composition of gravel deposits allows conclusions as to the surface features which prevailed during their formation. We do not doubt that continued observations of desert deposits will result in the establishment of sharp distinctions between them and fluviatile deposits, though it is not easy to distinguish between deposits of young rivers of a pluvial climate and those of mature rivers of a desert climate. Thus the study of deposits may afford us a crucial test as to the result of our study of forms.

Forms are always in the way of evolution; where destruction prevails on the land surface the existing forms are always in process of destruction; only where they are buried under new deposits are they conserved. The surface of every layer deposited on the land has been an old land surface. Thus the study of deposits also reveal forms of the past, and if we are accustomed to interpret the meaning of forms and deposits, we can read far older climatic conditions in deposits than are exhibited in the existing surface features of the land.

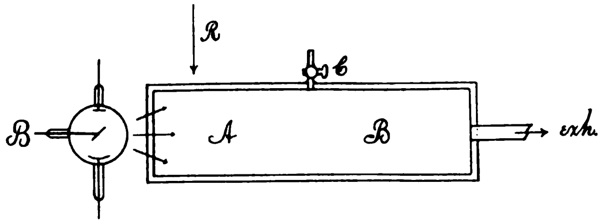
## Art. XI.—*Preliminary Results with an Objective Method of Showing Distribution of Nuclei Produced by the X-rays, for Instance;* by C. Barus.

**[The present research was carried out experimentally by Robinson Pierce, Jr., and myself, and I would gladly associate his name with mine at the head of this article, did he permit it.]**

1. *Introductory.*—By passing the X-rays into one end of a long rectangular (virtually tubular) condensation chamber and observing the effect produced after successive different intervals of time by the condensation method, evidence with a possible bearing on the origin of these nuclei was obtained. The coronas are distorted and at first occur on the bulb side of the apparatus only. The distribution of nuclei is inferred from the form of the corona.

The experiments described were all made with *strictly dust-free* saturated moist air, as both the method of precipitation and of filtration were applied prior to each experiment, and the exhaustion carried to a higher degree in the purifications than in the measurement. Furthermore as the exhaustions necessitated the use of short lengths of rubber tubing (1/2, 3/4, and 1 inch in bore in the different cases), the amount of cooling obtained does not directly correspond with the pressure difference, $\delta p$, owing to the resistance of the tube to the flow of air. The data, $\delta p$, each refer to a given type of apparatus but are satisfactory as relations, so long as this is not changed. Furthermore the $\delta p$ was so adjusted as to entrap all X-ray nuclei, to the exclusion of the normal, quasi-molecular nuclei of dust-free air.

1



2. *Apparatus.* — The method was purposely reduced to extreme simplicity and the apparatus is shown in the annexed diagram. $AB$ is the long rectangular condensation chamber of wood impregnated with resinous cement. The front and rear faces are plate glass through which the coronas may be observed. The other sides are lined within with thick cotton cloth, kept wet, and there is a layer of water at the bottom to

insure complete saturation of air. *C* is a stopcock leading to an efficient filter (not shown). Supersaturation is produced by sudden exhaustion at the B-end of the apparatus, while the A-end receives the radiation from the X-ray bulb *B′*. A large vacuum chamber was placed in connection with the exhaust pipe shown, through a wide stopcock, the details of which need not be explained. The X-rays used were not very penetrating, and were obtained from a soft bulb actuated by a small induction coil (4″ spark) and 3–5 storage cells. Two filters of solidly packed cotton were used, one 7 inches and the other 16 inches long. They were about equally efficient.

3. *Vertical radiation at one end of the trough, entering through wood.*—In the preliminary experiments the bulb was placed so as to radiate into the trough in the position shown at *R*, and kept in action 5 min. The effect was then observed by condensation at the pressure difference $\delta p = 17^{cm}$. Two results were noted: in the first place while the coronas obtained with the X-rays in bulky apparatus are usually of the smaller or normal type, the coronas seen in this shallow apparatus were often enormous, transcending the middle g–b–p corona (nucleation, $n = 100{,}000$ per cub. cm.). Even after two or three subsequent exhaustions, filtered air being added prior to each, large coronas were still in evidence.

In the second place, the coronas, and hence the nuclei, were observed chiefly on the A-side of the apparatus, under the bulb. Fearing that there might be some direct effect due to induced high potentials, the X-ray bulb was raised 10 and $20^{cm}$ above the trough, with results naturally smaller in magnitude but of the same kind. The following data may be given:

Table 1.—Number of nuclei, *n*, in thousands per $cm^3$. $\delta p = 17^{cm}$. Temp. about 20°: angular aperture $\phi = s/30$.

| | Bulb near trough ($2^{cm}$) | | | | | | Bulb $10^{cm}$ above trough | | | | Bulb $20^{cm}$ above trough. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of radiation | 5 min. | | 5min. | | 5 min. | | 6 min. | | 5 min. | | 6 min. | |
| | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* |
| Coronas on 1st exhaustion | * | — | * | — | * | — | 3·9 | 20·5 | 3·5 | 15 | 2·7 | 6·6 |
| " " 2d " | 5·9 | 6·8 | — | — | 6·5 | 100 | 2·7 | 6·6 | 2·7 | 6·6 | 1·9 | 2·2 |
| " " 3d " | — | — | — | — | 5·9 | 68 | — | — | — | — | — | — |

* Immense but too diffuse for measurement.

In all cases the first coronas were accompanied by dense rain and fogs frequently in horizontal strata, so that sharp measurements of aperture are generally out of the question. Moreover the first condensation is accompanied by turbulent displacement of fog-particles, and the contents of the receiver are thoroughly stirred up. After filling with filtered air and exhausting again, the coronas are therefore nearly uniform and alike on both sides. In the above table the nucleation produced decreases about as the inverse square of distance.

4. *Axial radiation entering one end of trough.*—Seeing that it is possible to retain the nuclei on one side of the trough, subsequent experiments were conducted with the X-ray bulb placed as shown in the figure. Moreover a smaller interval of radiation was selected, to more and more fully exclude the displacement of nuclei by diffusion. The angular diameters ($s/30$) of the coronas were measured with two gonimeters, one on each side (A and B) of the trough, the distance of the coronal centers from the bulb being about 20$^{cm}$ and 47$^{cm}$, respectively. The following table summarizes the results obtained, remembering that all initial coronas are coarse and blurred and accompanied by copious rain and fog, so that the diameters must be estimated.

BLE 2.—Number of nuclei in thousands per cm$^3$. $\delta p=17^{cm}$; angular diameter $\phi=s/30$.

| e of radiation ………… | 2·5 min. | | | | 3·5 min. | | | | 2 min. | | | | 2 min. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-side | | B-side | | A-side | | B-side | | A-side | | B-side | | A-side | | B-sid | |
| | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* | *s* | *n* |
| ona on 1st exhaustion | 4·5 | 32 | 2·2 | 3·3 | 4·5 | 32 | 2·2 | 3·3 | 4·0 | 22 | 2·0 | 2·5 | 2·5 | 5·2 | 0 | 0 |
| " " 2d " | — | — | — | .. | 3·2 | 11 | 3·0 | 9·3 | — | — | — | — | — | — | — | — |

The second coronas are obtained after refilling with filtered air and it is noteworthy that after the rains of the foggy first coronas fall out (which they do rapidly), there are abundant nuclei left for the next corona. As stated, the nuclei are now uniformly distributed, and the coronas persistent, while in the first exhaustion, apparently, certain larger particles captured all the moisture and removed it in a rainy precipitate.

It is to be observed moreover that the nucleations on the A and the B sides in these cases are on the average as 9 : 1 or in a larger ratio, while the ratio of distances is below 1 : 2, because the absorption of the wood is equivalent to a removal of the bulb. Hence the density of distribution falls off faster than the inverse cube. The contrast is even greater, because in the 2 or 3 minutes of radiation some nucleation must arrive on the B-side by convection and diffusion.

We were originally of the opinion that there is marked absorption of the nucleating power of X-rays, by the successive vertical layers of air from left to right, but it is best not to prejudge the case here.

5. *Continued for larger pressure differences.*—Several questions now present themselves for immediate decision:

viz., whether all the X-ray nuclei have been caught and in how far the exhaustions are below the point of spontaneous condensation of moist air. Accordingly larger pressure differences were applied. Table 3 gives a few examples.

TABLE 3.—Nucleations $n$ in thousands per cm$^3$. Time of exposure to X-rays, 3·5 min. Angular aperture $\phi = s/30$.

| $\delta p =$ | $17^{\text{cm}}$ | | $21^{\text{cm}}$ | | $31^{\text{cm}}$ | |
|---|---|---|---|---|---|---|
| Side | A | B | A | B | A | B |
| $s =$ | 4·6 | 1·8 | 3·9 | 2·1 | 2·8 | 2.5 |
| $10^{-3}n =$ | 35 | 1·9 | 27 | 3·5 | 11 | 7·8 |
| Ratio | 18 : 1 | | 7·7 : 1 | | 1·4 : 1 | |

Hence above $\delta p = 21^{\text{cm}}$ for this apparatus, nuclei show themselves on both sides and the question arises to what extent the normal air nuclei or ions have been captured. At $\delta p = 31^{\text{cm}}$, the fog particles condensed on X-ray nuclei probably drop out at once and the persistent corona observed is precipitated on the normal or inseparable air nuclei stated.

6. *Spontaneous condensation in moist air in the absence of X-ray nuclei.*—With the object of finding the pressure difference of exhaustion, $\delta p$, corresponding to the lower limit of spontaneous condensation of moist air without foreign nuclei, experiments were first tried with a cock 3/4 inch in bore, in the exhaustion tube. The results were identical on the A and the B sides, as follows:

TABLE 4.—Spontaneous condensation in saturated air. Angular aperture $\phi = s/30$.

| | $\delta p =$ | $24^{\text{cm}}$ | $31^{\text{cm}}$ |
|---|---|---|---|
| | $s =$ | 2·2 | 2·7 |
| Repeated, | $s =$ | 2·4 | 3·2 |
| " | $s =$ | 2·1 | — |
| Do., large filter, | $s =$ | 2·2 | 3·5 |
| Do. | $s =$ | 1·9 | — |
| Air over nights, | $s =$ | 2·0 | — |
| Mean | $s =$ | 2·1 | 3·1 |
| | $n =$ | 3,500 | 15,500 |

$\delta p = 22^{\text{cm}}$, $n = 0$

This indicates that at a pressure difference of about $\delta p = 22^{\text{cm}}$ for the given apparatus and dust-free moist air, spontaneous condensation with vanishing coronas begins, and that thereafter the coronas increase regularly.

In corroboration with the preceding, similar experiments were tried with an instantaneous valve, opening with a hammer, and having a clear bore of over one inch. The results shown in table 5 were identical on both sides but unexpectedly irregular. Alternation of large and small coronas in dust-free air, such as are here imperfectly shown, may be kept up indefinitely if strictly identical conditions are retained. Effectively, the large fog particles emit more nuclei, the smaller fewer nuclei for the next condensation in order, everything else remaining the same. The importance of these oscillations about the mean aperture, whether the emission is ionized or not, cannot be called in question, as I shall show elsewhere.

Table 5.—Spontaneous condensation of saturated air. Angular diameter $\phi = s/30$.

| Press. diff., $\delta p =$ | $19^{cm}$ | $19 \cdot 4^{cm}$ | $21 \cdot 4^{cm}$ | $24^{cm}$ |
|---|---|---|---|---|
| $s =$ | 2·3 | 3·4 | 3·3 | 4·4 |
| Repeated, $s =$ | 0 | 2·1 | 2.0 | 2·5 |
| " $s =$ | 0 | 0 | 3·0 | 4·3 |
| " $s =$ | 0 | 0 | 2·0 | 3·5 |
| " $s =$ | — | 0 | 3·5 | 3·3 |
| " $s =$ | — | — | 2·2 | 3·3 |
| Mean $s =$ | 0 | 0 | 2·7 | 3·6 |
| Mean $n =$ | 0 | 0 | 7,600 | 21,000 |

$\delta p < 20^{cm}$, $n = 0$

For $\delta p = 19 \cdot 4$ and below, therefore, no nuclei appeared after thorough cleaning. For $\delta p = 20^{cm}$ and above, i. e., at a somewhat lower pressure difference than before in consequence of more rapid exhaustion, spontaneous condensation begins. The large coronas are blurred.

Hence in neither case will spontaneous air nuclei be caught at $\delta p = 17^{cm}$, in the given apparatus.

7. *Possibility of producing nuclei by very sudden intense exhaustion.*—This condensation of moist air in the absence of foreign nuclei is usually considered due to the spontaneous ionization of the air, the available nuclei increasing in abundance, as with increasing pressure differences the sizes of captured nuclei are smaller, until the air molecule itself is approached. It follows then that the normal dust-free air always contains unstable systems.

Hence the question may well be asked, whether very sudden and intense exhaustion may not itself possibly be productive of nuclei. Thus if an unstable molecular configuration is just about to break down, it is conceivable that the tendency to break-down is accentuated by the violent treatment in question.

We made some experiments on this subject,* using a pressure difference $\delta p > 30^{cm}$, by placing a gold leaf electrometer, properly insulated, in the condensation chamber. The loss of charge in damp air is at first surprisingly small; nevertheless the experiments are very difficult and we were unable to come to a conclusion. A decision will probably be reached by aid of the oscillating coronas mentioned in § 6.

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* Investigations on the spontaneous condensation in moist air were first suggested by C. Barus, in Bull. U. S. Weather Bureau, No. 12, 1893, pp. 11-14, 48. They have since been fully treated in the masterly work of C. T. R. Wilson, Trans. Royal Soc. Lond., vol. 189, pp. 265-307, 1897; ibid., vol. 192, pp. 403-453. 1899.

8. *Successively increasing times of exposure to X-radiation.*—After this digression experiments were resumed with the apparatus as shown in the figure. The pressure difference $\delta p = 17^{cm}$ was used throughout, as this is well within the lower limit of spontaneous condensation for the given receiver, while coronas may be obtained with X-ray nuclei for pressure differences even lower than $\delta p = 10^{cm}$. Such coronas are vague, however, until the rain nuclei are thrown out, and on second exhaustion ($n$-39000, $s = 4\cdot8$ were usual values after 4 minutes ionization) they are naturally faint.

The immediate incentive to the work of the present section was given by the occurrence of elliptic distortions of coronas as shown in the following tables.

TABLE 6.—Distorted coronas. Increasing times of exposure to X-rays. $\delta p = 17^{cm}$. Coronal center $19^{cm}$ (A-side) and $46^{cm}$ (B-side) from bulb. Angular aperture $\phi = s/30$.

| Time | 2 min. | |
|---|---|---|
| Side | A | B |
| First exhaustion, | $s = 4\cdot5$, elliptic, strong | 1·0? faint, circular |
| Second " | $s = 2\cdot7$, circular | 2·4 circular |
| First " | $s = 4\cdot6$, elliptic, strong | 0·0 |
| " " | $s = 4\cdot6$, " " | 0·0 |

TABLE 7.—Preceding table continued.

| Time | 1 min. | | 2 min. | | 3 min. | |
|---|---|---|---|---|---|---|
| Side | A | B | A | B | A | B |
| $s =$ | 3·1, round, strong | 0 | 4·1, elliptic, strong | 0 | 5·8, ellipse, larger and distorted | 0 |

On second exhaustion, after refilling with filtered air, the coronas were nearly identical on both sides.

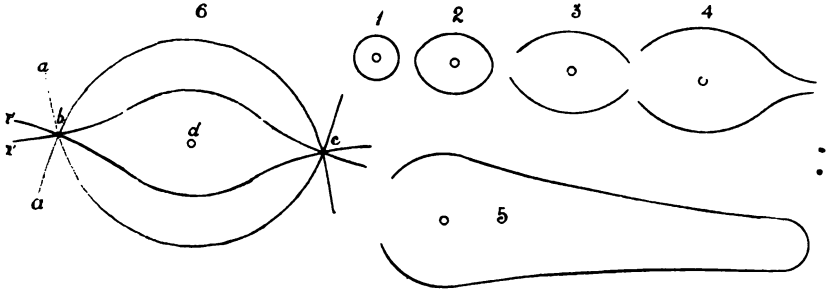
A series of observations was now systematically carried out, unfortunately with somewhat weaker radiation. After 1, 2, and 3 minutes of exposure, respectively, the coronas on the A-side were round to roundish (cf. figs. 1 and 2), of gradually increasing strength and density, and with rainy precipitation and fog usually marked. There was nothing on the B-side even after 6 minutes of exposure.

After 4 minutes (cf. fig. 3), the corona became spindle-shaped, $s = 5{\cdot}4^{\text{cm}}$ in major axis, accompanied by rain from horizontal layers of fog.

After 6 minutes of exposure to the X-rays, the coronas underwent remarkable distortion, becoming gourd-shaped (fig. 4), often with a long, serpentine neck, dipping into the B-side of the condensation chamber. The length of figure on the goniometer was about $6{\cdot}8^{\text{cm}}$, the outline being orange and the field within greenish. Rain and fog abounded. The coronas on second exhaustion (after adding filtered air) were g–b–p, $s = 4{\cdot}9$, $n = 42000$ and w–r–g, $s = 4{\cdot}5$, $n = 32000$, on the A and B sides respectively. The experiment was repeated with like results.

After 8 and 11 minutes of exposure, both the A- and B-side became the seat of the now wedge-shaped corona (cf. fig. 5), greenish within and orange in outline. There was much rain and fog.

2



The figures, 1–5, are seen immediately after the exhaustion. A moment later there is a storm-like disturbance in the condensation chamber, accompanied by rain and fog. Hence the distribution of nuclei found on exhaustion is incompatible with a persistent distribution of fog particles. In fact the first coronas usually fall out rapidly, showing the occurrence chiefly of large fog particles in spite of the horizontal extent of the corona. The second coronas are circular and persistent, whence a nearly uniform distribution of nuclei may be inferred.

9. *Symmetrically graded sizes or numbers of fog particles.*—Since the coronas obtained all show an unmistakable tendency to horizontal symmetry with reference to the longitudinal axis of the condensation chamber, the nuclei to which the coronas are due must either originate in, or else be absorbed by, the top and bottom of the apparatus. Nuclei originating or lost at the front and rear faces are nearly uniformly distributed normal to the line of sight and produce circular coronas. Nuclei origi-

nating or lost at the left hand end of the chamber will additionally distort the corona, and such distortion is in evidence.

Mere inspection of the coronas, 1–5, shows that they are larger for fog particles near the axis, and smaller for particles near the top and bottom of the condensation chamber. Hence it is next necessary to explain that the details of the distorted coronas observed actually correspond with a gradation of the number of *effective* or available nuclei, from the axis outward on all sides. In the case of linearly graded fog particles increasing in diameter, $\delta$, from bottom to top ($h$), it appears that the equation of the apertures, $s$, of the loci* of like color of the coronas is

$$s = -\frac{\delta_0}{a \sin \phi}\left(1 - \sqrt{1 + \frac{2 a s_0 \sin \phi}{\delta_0}}\right),$$

where $s_0$ is the aperture of the particles of diameter, $\delta_0$ in the horizon or plane of sight, and $\phi$ the angle in polar coördinates between the radius vector to the part of the corona in question and the horizontal, the origin being at the center of the corona. Finally $\delta = \delta_0 - ah$, where $2h = s \sin \phi$. Such coronas when the gradation becomes marked are *campanulate* in outline, finally becoming basin-shaped.

In the present case, however, there are two symmetrical distributions of this kind, i. e., increasing diameters of fog particles from the axis of the chamber towards the top and the bottom. Hence pairs of intersecting curves, two examples of which are given in figure 6 ($a' > a$), show the coronas to be anticipated, if the remote parts beyond $b$ and $c$ of the corona are ignored, as they have no bearing on the symmetrical case, and only the curves surrounding the spot of light, $d$, admitted. In other words, as the distance $bc$, varying with the number of axial nuclei and the distribution constant $a$, increase, all the figures 1, 2, 3, 4, 5, may be logically evolved.

On the left end face, moreover, there would be special interference with the distribution of nuclei giving rise to the corresponding distortion seen in the coronas. Further distortion due to the decrease from left to right of the intensity of the radiation must also be apparent, and the gradient of distribution will be slightly altered by diffusion. One may note that if anything issues from the walls of the vessel, it comes as abundantly out of the water below as out of the wet cloth above.

10. *Origin of nuclei at the walls of the receiver.*—As has already been suggested, the observed gradation of fog particles may result from the (real or virtual) evolution of effective nuclei at the top and the bottom of the apparatus, in conse-

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* Barus: this Journal (4), xiii, p. 309, 1902.

quence of the impact of X-rays on those parts, associated with secondary radiation. There is much electric evidence against such an explanation; nevertheless it is worth a brief examination.

The enormous coronas which have been obtained with the above (shallow) apparatus as compared with the small coronas seen in the cases of more bulky apparatus is in keeping with this view. Again, the rapid decrease of the nucleating power of the X-rays is to some extent referable to the increasing obliquity of the rays.

The observed distortion of coronas is clearly due to a gradation of nuclei, *either as to size, or number*, or both. If efficient nuclei issue from the top and bottom they must be present in greatest number near those parts of the apparatus, and consequently the largest diameter of coronas should apparently be found there. But if the largest number of effective nuclei is present near the top and bottom, the tendency to growth by cohesion will also be most marked in those regions. Hence the largest nuclei must be looked for nearest the top and bottom, while the gradation in size decreases regularly towards the axis. The large nuclei, therefore, may be sufficiently numerous near the walls to capture all the available moisture on condensation, leaving the small nuclei without a load of water and unable to descend. Hence the marked rain effect, the rapidity with which the first coronas usually drop out, the turbulent motion which succeeds condensation, the occurrence of large persistent coronas on second exhaustion even after the first coronas have quite dropped out, etc.

Finally one may note that secondary radiation issuing from the top and the bottom of the condensation chamber would accentuate the present effect.

Thus it seems not unreasonable to infer that nuclei are produced by the impinging X-rays in much the same way in which they are produced by high temperature (ignition), or by high potential; and the question arises whether the nuclei thus easily set free may not be associated with the electrons to which the cohesions between the molecules may be ascribed.

11. *Absorption of the ions at the walls of the receiver.*—If the nuclei due to the ionization of air by the X-rays are absorbed at the walls of the receiver* a diffusion gradient will be established, resulting in a decreasing number of nuclei from the axle outward, a distribution the reverse of the preceding. The observed distortion will, therefore, here be due to a gradation in the number of nuclei.

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* A number of similar cases have been worked out in Smithsonian Contributions, No. 1309, 1901, "Experiments with ionized air;" and ibid., No. 1373, chapter v, 1903.

The difficulty in the present instance, however, seems to be fatal; for no reason is suggested why the coronas on second or third exhaustion do not eventually show flowerlike distortion, which they never do. In other words, it is here tacitly assumed that only the ions in the "nascent" state, as it were, are appreciably diffusible, while the nucleus is relatively a fixture. Again, the effect of secondary radiation is ignored.

12. *Conclusion.*—To decide between these hypotheses it is necessary to guide the X-rays by screens, suitably placed both on the inside and the outside of the apparatus; but these experiments are still in progress.

Here there is room only for a final remark. Whenever nucleation and ionization are associated as the outcome of any process (physical or chemical), the former is generated proportionally to the latter, in such a way that each is produced at its own rate depending on incidental conditions. This is best worked out with water nuclei. The subsequent life-history of the nucleation and the ionization is distinct, nuclei being surprisingly persistent, ions by contrast characteristically fleeting. Hence it seems to me to be best in keeping with all the data in hand, to regard the nucleation as the product which owes its growth or origin to the expulsion of the corpuscles representing the concomitant ionization. Ignition and high potential nuclei, X-ray and radiation nuclei in general, phosphorus and water nuclei, produced throughout in strictly dust-free air, all admit of this account of their occurrence and properties. There is no observable case of a process producing ionization without nucleation, although there are many cases of nucleation free from ionization.

It should be noticed that to produce the condensation on the X-ray air nuclei here in question, less than a twofold supersaturation is needed; whereas in case of condensation on ions the supersaturation prescribed is three to fourfold. The two views are not, therefore, mutually exclusive. Moreover, if initially, i. e., for short exposures and nuclei in the extreme state of fineness antedating growth, the nucleus is supposed to have ejected but one electron per nucleus (an assumption which in one form or another must be made in any explanation), the present view is in no way incompatible with J. J. Thomson's method of measuring the charge of one electron. Finally if a nucleus like that of phosphorus shows a tendency to grow continuously until it finally appears as part of a visible smoke, there may be continuous ejection of electrons within certain limits, as the growth matures. Electric conduction through a gas freighted with these nuclei would obey Ohm's law, as is actually the case for phosphorus.

Brown University, Providence, R. I.

## Art. XII.—*Radio-active Measurements by a Constant Deflection Method;* by Howard L. Bronson.

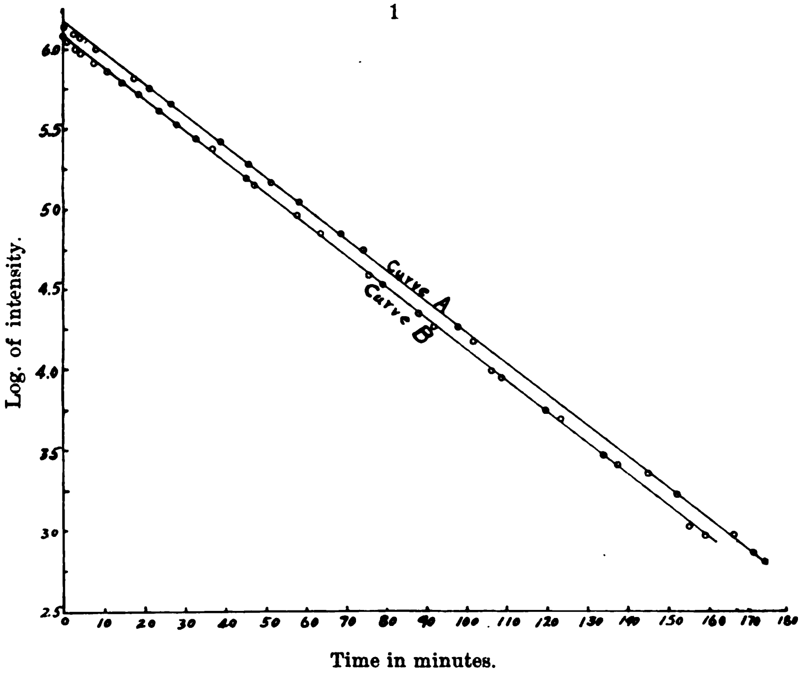
The ordinary method of using an electrometer for comparing ionization currents through gases has been to measure the rates of movement of the needle. The ionization currents are then proportional to these rates, if the following conditions are fulfilled: (1) that the capacity of the system remains constant, (2) that the deflection is proportional to the potential of the quadrants, (3) that the lag of the needle behind the potential is the same for different rates. In some cases these conditions are closely fulfilled, but in others, especially where the needle is moving rapidly, the last condition and probably the first are not. The introduction of additional capacity into the system, while it reduces the rate of motion of the needle, creates the added difficulty of comparing capacities, which not only takes considerable time but is never entirely satisfactory. Another difficulty with this method is that it is practically useless in the case of rapidly changing ionization currents. The desirability, therefore, of a more direct and rapid method of measurement is evident.

If, as usual, one pair of quadrants of the electrometer is connected to earth, and the other pair is not only connected to the testing vessel but also to earth through a very high resistance, it is easily seen that an ionization current in the testing vessel will charge the quadrants until the discharge current through the high resistance is equal to the ionization current. In this case the current will be proportional to the potential of the quadrants, that is, to the deflection of the needle.

Resistances of the order $10^{11}$ ohms made of pure amyl alcohol and of carbon on glass were tried, and gave results which compared favorably with those obtained by the "rate" method. The results, however, were not satisfactory, because in the case of the liquid resistance there seemed to be a variable polarization, whereas the resistance of the carbon was not perfectly steady. Professor Rutherford then suggested the possibility of using an ionization current in place of the conduction current through a high resistance. For this purpose he furnished a very radio-active bismuth plate from Dr. Sthamer of Hamburg. The activity of this plate was due to a deposit of the so-called radio-tellurium of Marckwald, which has such a long period of decay that it remains practically constant during any short experiment.

The bismuth plate was earthed and covered with a very thin sheet of aluminium to avoid contact potential difference. Another aluminium plate was placed parallel to this and connected to the same quadrants as the testing vessel, and the whole was protected from air currents. The electrometer had a sensitiveness of about 150 scale divisions per volt, and with the plates $2^{\text{cms}}$ apart, the ionization currents were practically proportional to the deflections throughout the entire length of the scale (500 divisions). When the distance between the plates was increased to $2{\cdot}7^{\text{cms}}$ the same deflection was produced by an ionization current only one third as large, that is, the sensitiveness of the apparatus was tripled; on the other hand, the current was proportional to the deflection for only about 150 divisions. The currents measured varied from about $10^{-13}$ to $10^{-10}$ amperes.

1



The advantages of this method are obvious; deflections are independent of the capacity, measurements can be made over a large range without readjustment, and observations can be taken in as rapid succession as desired. In some cases observations were taken as often as once in five seconds. Figs. 1 and 2 show the accuracy which can be obtained by single sets of observations.

A and B, fig. 1, are two similar logarithmic decay curves of the excited activity of actinium, and should therefore be parallel. The time 0 was at least 20 minutes after the emanation was removed, so that the initial rise of the excited activity is not shown. The equation of the decay of any radio-active substance is given by Rutherford (Radio-activity, p. 258) as $\frac{I}{I_0} = e^{-\lambda t}$. From curve A, λ is found to be 0·0193, and from curve B, 0·0195, where the time is measured in minutes. The mean of these two values gives 35·7 minutes as the time required for the excited activity of actinium to decay to half value. This is a rather shorter time than was found by Debierne (Comptes Rendus, No. 138, p. 491), and verified by Miss Brooks (Phil. Mag., Sept., 1904). This smaller value, however, was confirmed by a large number of observations taken by the "rate" method. The values thus obtained varied considerably, but their mean was about 36 minutes.

2

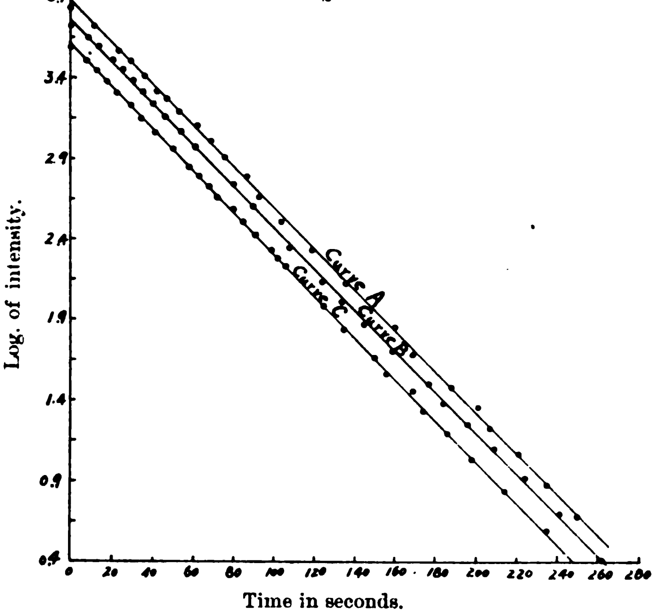


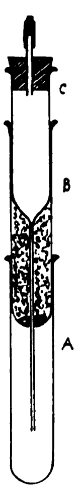
Fig. 2 shows three logarithmic decay curves for thorium emanation, which on account of its rapid rate of decay has been found so difficult to measure. By this method the observations for the three curves were taken in about thirty minutes. The value of λ obtained from curve A is 0·0129, from curve B is 0·0127, and from curve C is 0·0128,—a very satisfactory agreement for single sets of observations. A mean value of these λ's gives about 54 seconds as the time taken for the emanation to decay to half value, which agrees fairly well with the value 51·2 seconds recently obtained by C. Le Rossignol and C. T. Gimingham (Phil. Mag., July, 1904).

**Macdonald Physics Building,**
**McGill University, Dec. 20, 1904.**

## ART. XIII.—*A Convenient Apparatus for Determining Volatile Substances by Loss of Weight;* by J. LEHN KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxiii.]

OF THE various forms of apparatus designed for the determination of volatile products of reactions, some are cumbersome and many require for their construction skill in glass-blowing. The apparatus here described is light and easily made from three test-tubes, modified and fitted as shown in the figure. The test-tube, A, is changed in no way from its original form; B is perforated, in the bottom, with a hole about $1^{cm}$ in diameter and fits tightly within A; and C, so selected that it fits loosely within B, is drawn out to a small capillary tube.



When the apparatus is to be used, the capillary of C is pushed through the hole of B, packed loosely with cotton; B is filled to the depth of from $6^{cm}$ to $8^{cm}$ (about two-thirds of its contents), with granular calcium chloride; and B and C are adjusted as shown.

To the test-tube, C, is fitted a one-holed stopper, through which passes a short glass tube which is to be closed by a rubber cap and plug. Upon removing the plug, and applying suction to the short tube, the reagent employed to liberate the volatile product to be determined is drawn up through this capillary until C is sufficiently filled. Upon replacing the plug the reagent remains within C, held by atmospheric pressure.

The tubes A and B may be so selected that very little of the product evolved can escape between them, but in case they fit very loosely, a ring of paraffine melted into the mouth of A, about B, by means of a hot iron or wire, seals the joint securely. A very convenient way to attach the paraffine is to melt it between A and another tube, which fits A, as does B, and may be removed by a turning motion, leaving the ring into which B will fit, and which then requires very little heating to make a tight joint. If care be used in taking apart A and B, at the close of an experiment, such a ring of paraffine remains in place and may be used many times without replacement, being remelted by a touch of the hot wire before every new experiment.

In making a determination, the substance under examination is weighed and placed in the bottom of A. The reagent to be employed, $10^{cm^3}$ to $15^{cm^3}$, is drawn into C, and held there in the manner described. The test-tube A is slipped over B, and this joint is sealed with paraffine, as has been shown. The apparatus is wiped, placed on the balance, and weighed.

Upon removing the cap from the small tube in C, the reagent runs from C into A. The volatile product is formed, is forced upward through the drying column of calcium chloride, and escapes through the annular space between B and C. When the action ceases, a current of dry air is forced through C, to drive all the volatile product from the apparatus, the cap is then replaced, and the whole placed on the balance to be weighed. The loss of weight represents the volatile product.

The following results show the accuracy which may be expected when carbonates are treated in the apparatus with dilute hydrochloric acid:

TABLE I.

| | Taken.<br>grm. | Found.<br>grm. | Error.<br>grm. |
|---|---|---|---|
| Calcium Carbonate. | 0·2000 | 0·0879 | −0·0001 |
| | 0·2000 | 0·0878 | −0·0002 |
| | 0·2000 | 0·0879 | −0·0001 |
| | 0·2000 | 0·0879 | −0·0001 |
| | 0·5000 | 0·2197 | −0·0003 |
| | 0·5000 | 0·2196 | −0·0004 |
| | 0·5000 | 0·2194 | −0·0006 |
| | 0·5000 | 0·2198 | −0·0002 |
| | 0·5000 | 0·2197 | −0·0003 |
| | 0·5000 | 0·2197 | −0·0003 |
| Barium Carbonate. | 0·5000 | 0·1134 | −0·0011 |
| | 0·5000 | 0·1137 | −0·0005 |
| | 0·5000 | 0·1137 | −0·0005 |
| | 0·5000 | 0·1136 | −0·0006 |
| Strontium Carbonate. | 0·5000 | 0·1485 | −0·0004 |
| | 0·5000 | 0·1486 | −0·0003 |
| | 0·5000 | 0·1485 | −0·0004 |

In Table II are included the results of some experiments made to determine the weights of hydrogen liberated by the action of magnesium and zinc, upon dilute hydrochloric acid.

TABLE II.

| | Taken.<br>grm. | Found.<br>grm. | Error.<br>grm. |
|---|---|---|---|
| Magnesium Metal. | 0·1000 | 0·0087 | +0·0003 |
| | 0·1000 | 0·0085 | +0·0001 |
| | 0·1000 | 0·0084 | ±0·0000 |
| | 0·1000 | 0·0084 | ±0·0000 |
| | 0·1000 | 0·0083 | −0·0001 |
| Zinc Metal. | 0·2000 | 0·0061 | ±0·0000 |
| | 0·2000 | 0·0062 | +0·0001 |
| | 0·2000 | 0·0062 | +0·0001 |
| | 0·2000 | 0·0060 | −0·0001 |
| | 0·2000 | 0·0061 | ±0·0000 |

Determinations of the nitrogen liberated from urea, ammonium oxalate, and ammonium chloride, by action of sodium hypobromite, are given in the following table:

TABLE III.

| | Taken. grm. | Found. grm. | Error. grm. |
|---|---|---|---|
| Urea. | 0·1000 | 0·0469 | +0·0003 |
| | 0·1000 | 0·0467 | +0·0001 |
| | 0·1000 | 0·0467 | +0·0001 |
| | 0·1000 | 0·0468 | +0·0002 |
| | 0·1000 | 0·0467 | +0·0001 |
| Ammonium Oxalate. | 0.1000 | 0·0204 | +0·0007 |
| | 0·1000 | 0·0197 | ±0·0000 |
| | 0·1000 | 0·0198 | +0·0001 |
| | 0·1000 | 0.0198 | +0·0001 |
| | 0·1000 | 0·0196 | —0.0001 |
| Ammonium Chloride. | 0·1000 | 0·0264 | +0·0002 |
| | 0·1000 | 0·0265 | +0·0003 |
| | 0·1000 | 0·0261 | —0·1000 |
| | 0·1000 | 0·0263 | +0·0001 |
| | 0·1000 | 0·0261 | —0·0001 |

I wish to thank Prof. F. A. Gooch for his advice and kind assistance.

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *Canyon Diablo Meteorite.* — MOISSAN has made a new examination of a portion of this celebrated meteorite. When the mass was cut with a saw several very hard nodules were encountered which interfered greatly with the cutting operation. Upon dissolving a large mass of the meteorite, 53 kg., in hydrochloric acid, it was evident that the iron was not homogeneous, for it was attacked very irregularly. The hydrogen set free by this dissolving contained hydrocarbons, hydrogen sulphide, and hydrogen phosphide.

Certain samples taken from the exterior gave the following percentages: Iron, 95·64; nickel, 1·66. Iron, 95·26; nickel, 2·56. Iron 94·03; nickel, 3·61. Iron 96·31; nickel, 1·83. A sample of specific gravity 7·703, taken from the interior, gave: Iron, 95·370; nickel, 3·945; phosphorus, 0·144; insoluble in HCl, 0·260; silicon, traces; sulphur, traces; carbon, not determined.

A nodule, cut out with a chisel, gave the following analysis: Iron, 66·95; nickel, 1·93; cobalt, traces; sulphur, 22·15; phosphorus, 2·37; silicon, small quantity; magnesium, traces; carbon, 1·96.

The residue from dissolving 53 kg. in hydrochloric acid weighed 800 g. It consisted of a coarse powder, containing brilliant needles and cubes, both of which gave analyses corresponding closely to the formula $P_2Fe_8$, and contained only traces of nickel and carbon. In the residue which remained after treatment with concentrated hydrofluoric acid and boiling sulphuric acid, characteristic green hexagonal crystals of carbon silicide (carborundum) were found. This is the first time that this compound has been found in nature.

A part of the carbon in the meteorite escaped in the form of hydrocarbons upon dissolving it in hydrochloric acid, but the 800 g. of residue previously referred to contained 5·04 per cent of carbon. Five forms of carbon were noticed in this residue: A light, impalpable powder; jagged, slender fragments of a light color, which seemed to have been agglomerated by pressure; graphite, very rarely crystallized; smooth, black diamonds, abundant, but very small; transparent diamonds in the form of octahedrons with rounded edges.—*Comptes Rendus*, cxxxix, 773. H. L. W.

2. *Metallic Calcium.*—An examination of some of the chemical and physical properties of this metal has been undertaken by K. ARNDT. The metal is now produced on the large scale by the electrolysis of fused calcium chloride, so that it is easily procured. Metallic calcium is ductile, and can be hammered and chiselled like brass, and it clogs a saw or a file. The fresh surface of the metal is brilliant, but it becomes yellowish rapidly, particularly in moist air. (The metal was formerly supposed to possess a

yellow color.) A piece of calcium reacts slowly with water on account of the difficult solubility of the hydroxide, but if a little hydrochloric acid is added, the evolution of hydrogen is violent. A sample of the commercial metal was found to contain 0·2 per cent of silicon and 0·3 per cent of aluminium with traces of iron. The hydrogen produced from it was very pure, and contained no appreciable amount of acetylene or other hydrocarbons. The specific gravity of the metal was found to vary considerably in different samples; a very pure specimen gave 1·52 as the result. In this investigation the melting-point was not very exactly determined, but it was near 800°. The metal begins to vaporize in a vacuum below its melting-point, and forms beautiful crystals which are free from silicon and aluminium. The vapor of calcium reacts very energetically—much more so than magnesium—with any residue of air that may be in the tube in which it is heated. In this way a very complete vacuum may be obtained from an imperfect one.—*Berichte*, xxxvii. H. L. W.

3. *The Use of Dried Air in Blast-furnaces.*—The employment of air dried by refrigeration, a process due to Mr. Gailey and applied at the Isabella Furnaces near Pittsburgh, has received considerable attention of late in the technical journals. The advantage attributed to the removal of the moisture from the air used for blast depends upon the fact that water is decomposed by incandescent carbon with the absorption of heat, and with the direct loss of carbon, by the reaction

$$C + H_2O = CO + H_2,$$

and it is claimed that a gain of 20 per cent is made in the efficiency of the fuel.

The process has been recently discussed by LE CHATELIER, in France, from a scientific point of view, and he maintains that the gain in efficiency attributed to the process is about four times greater than the theoretical maximum obtained by calculation. He puts forward the view that the advantage is partly due to a possible effect of the dryness of the air upon the removal of the sulphur from the pig-iron, and supports this opinion by the results of experiments in which it was found that dry carbon monoxide free from hydrogen does not remove sulphur from heated calcium sulphide, while the gas when mixed with hydrogen removes it with considerable rapidity.—*Comptes Rendus*, cxxxix, 925.

H. L. W.

4. *Trisulphoxyarsenic Acid.* — MCCAY and FOSTER have prepared the salts

$$\begin{array}{l} Na_3AsOS_3 \cdot 11H_2O, \\ NaSrAsOS_3 \cdot 10H_2O, \\ Ca_3(AsOS_3)_2 . 20H_2O, \\ K_3AsOS_3 \cdot 7H_2O, \text{ and} \\ KBaAsOS_3 \cdot 7H_2O, \end{array}$$

which represent a heretofore missing member, $H_3AsOS_3$, of a series of acids intermediate between $H_3AsO_4$ and $H_3AsS_4$, concerning which most of our knowledge is due to McCay and his pupils at Princeton University, viz.,

$H_3AsO_3S$,
$H_3AsO_2S_2$, and,
$H_3AsOS_3$,

These sulphoxy acids have not been isolated, and only the first two appear to exist in dilute solutions.

The trisulphoxyarsenates are usually colorless, crystalline, rather unstable compounds. The sodium salt is prepared by acting in the first place upon arsenic pentasulphide with a large excess of magnesium oxide in the presence of water, whereby the sulphide dissolves; then precipitating magnesium hydroxide by means of sodium hydroxide and removing it by filtration, adding alcohol to the liquid until a turbidity begins to form, and finally cooling to crystallization.—*Zeitschr. anorgan. Chem.* xli, 452. H. L. W.

5. *The Electrolysis of Solid Electrolytes.*—It has been found possible by **Haber** and **Tolloczko** to electrolyze solid barium chloride at a temperature about 400° below its melting-point. When barium carbonate had been mixed and fused with the barium chloride, carbon was produced at the cathode in quantities corresponding to the electric current employed, but when the barium chloride was free from carbonate, barous chloride formed quantitatively. In both cases the result may be assumed to be due to the reaction of metallic barium with the substances present. The experiments were conducted in nickel crucibles with careful regulation and measurement of the temperatures. Attempts to electrolyze sodium hydroxide were not successful when the substance was perfectly solid.—*Zeitschr. anorg. Chem.*, xli, 405. H. L. W.

6. *The Determination of Fluorine in Wine and Beer.* — On account of the frequent use of sodium fluoride as a preservative, particularly for French, Spanish, and Greek sweet wines, and because of the poisonous effect of this preservative, which appears to have been established by the results of several investigators, **Treadwell** and **Koch** have undertaken the examination of various methods which appeared applicable to the determination under consideration.

No easy method for performing this difficult determination was found, but interesting results in regard to the accuracy of the standard methods, and the limits within which fluorine can be detected qualitatively, were obtained. A slightly modified apparatus for the determination according to Penfield's method is described and figured.—*Zeitschr. analyt. Chem.*, xliii, 469. H. L. W.

7. *Direction and Velocity of Electric Discharges in Vacuum Tubes.*—Wheatstone in 1835, by means of a rotating mirror, arrived at the conclusion that this velocity was not less than 8 x $10^7$ cm. per second; Plücker from observations in a magnetic field, concluded that the discharge emanated from the positive elec-

trode. Spottiswoode and Moulton found that the time which the positive electricity needed to traverse the tube was shorter than that which the negative electricity required to leave the cathode. They believed that the time occupied by a discharge to traverse a metallic conductor was much shorter than the time required through a discharge tube. J. J. Thomson took a discharge tube $15^m$ long, blackened it except at two points; threw an image of these two points on a cylinder. When the cylinder was at rest, the points or slits were directly over each other; when the cylinder was set in rapid revolution the images of the points separated. When the current was reversed, the images exchanged position. He concluded that the discharge was independent of the nature of the electrodes and always proceeded from the anode to the cathode, and that for a pressure of $0{\cdot}8^{mm}$ the velocity of the discharge was approximately half that of light. E. Wiedemann and G. C. Schmidt have shown that under certain conditions an apparent velocity of $200^m$ per second can be observed. Wüllner, Rhigi and others have noticed an extraordinarily slow velocity. On account of the divergence of results J. James has studied the question of the velocity in discharge tubes by means of the Abraham-Lemoine method of measuring small intervals of time. This method consists in employing changes in polarization of light in the magnetic field, or by electric stress. By these means a time interval of one hundred millionth of a second can be detected. James gives an analytical discussion of his employment of the method which he used to study the discharge of the electric spark in air, and also in a discharge tube. He found results which did not agree with those obtained by J. J. Thomson. They did agree, however, with those of Spottiswoode and Moulton. Further investigations are needed to determine whether from a study of the kind of illumination one can draw conclusions in regard to velocity.—*Ann. der Phys.*, No. 15, 1904, pp. 954–987.

J. T.

8. *Extinction of the Electric Spark.*—Wireless telegraphy and the study of N-rays give a great interest to the study of the electric spark. John Koch discusses conditions of residual charges of condensers and the fall of potential and other conditions which accompany or cause extinction. He concludes that the causes which lead to this extinction are purely electrodynamic and are identical with those connected with the dying out of the voltaic arc. The author concludes that Heydweiller's contention, that the development of energy is proportional to the time of discharge and independent of the current strength, is true only to a first approximation, when very great resistances are in the circuit.—*Ann. der Phys.*, No. 15, 1904, pp. 866–905. J. T.

9. *Exhaustion of Geissler Tubes by the Electric Current.*—It has often been noticed that the degree of exhaustion in Geissler tubes, and notably in X-ray tubes, is changed by long continuance of electrical discharges. At first the heat of the discharge increases the pressure and then there comes a lowering of the pressure

which indicates occlusion or absorbtion of the rarified gas in the glass walls of the tubes. **Eduard Riecke** has studied this soaking in effect in the case of nitrogen. He compares the effect of mere gas absorbtion with the absorbtion induced by the electrical discharges and estimates the connection between the strength of current and the resulting diminution of pressure.—*Ann. der Phys.*, No. 15, pp. 1003–1009. J. T.

10. *The N-rays.*—Authorities are still divided in regard to the existence of these rays. A. **Broca** (Archives d'El Medicale, pp. 723–740, Oct. 10, 1904) points out that the observation of these rays is an extremely delicate one ; in his own case it was six weeks before he could see the rays. He submitted himself to an elaborate course of training and he gives an account of the best way of studying the rays. He dwells upon the necessity of observing physiological conditions. Thus the eye must be adapted to almost completed darkness or at least to very feeble lights. The observer must be left with his mind free, all instrumental changes being intrusted to another. The effects due to heat must be borne in mind ; for the physiological radiations can be entirely swamped by the heat effects. The two effects can be distinguished by the slight lagging (up to a few seconds) behind of the effect due to the N-rays, such lag being much greater in the case of the heat effect ; and on the cessation of the action the difference of lag is even greater. The N-ray effect may also be distinguished by the different behavior when viewed normally, at 45°, and at grazing incidence.—*Science Abstracts*, Dec. 27, 1904.

It is stated in the Revue Scientifique of Nov. 26 that M. d'Arsonval has been able to reproduce the N-rays and to show that they are not due to heat. Mascart is stated to have observed the phenomena with D'Arsonval.—*Nature*, Dec. 15, 1904.

J. T.

11. *The Recent Development of Physical Science ;* by **William Cecil Dampier Whetham**, M.A., F.R.S., Fellow of Trinity College, Cambridge. pp. 445, 8vo. Philadelphia, 1904 (P. Blakiston's Son & Co.).—At a time like the present, when the public in general is more than ever before keenly alive to the progress made in science, it is most useful to have the topics of immediate interest presented in a form so simple and clear that anyone who is well grounded in the fundamental principles can gain a good understanding of what is being done. This is eminently true of the book in hand, which, in a series of eight chapters, gives an admirable presentation of some of the subjects in physics, which are just now of greatest interest and in which progress has been and is being made. The author has a thorough command of his subject, and has also had the advantage of assistance from various specialists in the different lines. Some of the subjects dealt with in the eight chapters are : the liquefaction of gases, fusion and solidification, solution, electric conduction through gases, radio-activity, atoms and ether. The frontispiece is a representation of the well-known statue of Newton, and portraits of Lord

Kelvin, J. J. Thomson, van't Hoff, with other illustrations, are scattered through the volume.

12. *Outlines of Physiological Chemistry;* by S. P. **Beebe** and B. H. **Buxton.** 195 pp. New York, 1904 (The Macmillan Co.). —The title of this little book is perhaps somewhat misleading if it gives the impression of any systematic review of the subject. The aim of the authors is rather to deal with the theoretical side of the various chemical questions arising in physiology, and to explain the nature of the more important reactions with which the student has to deal. The book includes chapters on the theory of solutions, and on the chemistry of the carbon compounds ; the more distinctly physiological part is almost entirely devoted to the proteids and to enzyme action. The current theory of immunity is also outlined. L. B. M.

## I. Geology and Mineralogy.

1. *Geological Survey of Canada,* Robert Bell, Acting Director. Annual Report, vol. xiii, 1900, 747 pp., 8 maps, 15 pls. —The Canadian survey reports are always of interest because of new territory explored and the geological reconnoissance which is being carried on. The present report shows that a great amount of work in several lines is being accomplished at small expense. The principal papers bound in the volume are: Exploration of East Coast of Hudson Bay and Geology of Nastapoka Islands, by A. P. Low ; Parts of Saskatchewan, Athabaska, and Keewatin, by J. B. Tyrrell, and also by D. B. Dowling ; Basin of Nottaway River, by Robert Bell ; Geology and Petrography of Shefford Mountain, Quebec, by J. A. Dresser. These papers have been previously issued separately.

Dr. Low's investigations show that the land about Hudson Bay is now 700 ft. above the level during the ice age. He finds no evidence of present elevation. (For the contrary view see article by Dr. Bell in Geol. Soc. Am., 1895.) The key to the stratigraphic problems in the Cambrian, which shows buckling and nearly horizontal movement, is found in the contraction of intruded granite masses. "The contacts of the bedded rocks and granites are usually unconformable and appear to be due to a nearly horizontal movement of the bedded series subsequent to the intrusions of the granite, due to pressure acting from outside the great areas of granite. This series of sedimentary rocks being close to the surface broke as does ice upon the shore when pressed from seaward and piled cake on cake not only upon unyielding granite but upon themselves."

2. *The Iowa Geological Survey,* Samuel Calvin, State Geologist: Vol. xiv, Annual Report of 1903, 655 pp., 38 pls., 132 fig.— The last annual report of the Iowa Geological Survey is chiefly economic in character, and in addition to the annual statistics contains an extensive treatment of clays and clay products in general with special reference to the Iowa deposits. At the present time

the clay products of Iowa stand second in value only to the output of coal. The survey is also collecting data relative to the artesian waters in Iowa, and plans to publish a report on the same. The U. S. Survey has completed the topographical work in northeastern Iowa, so that the state survey will now work out the details of geology in that section. An investigation is in progress regarding the coals of Iowa, their occurrence, physical and chemical characteristics, geological and geographical relations.

3. *Glaciation in South Africa.*—At the October meeting of the Geological Society of South Africa, Mr. M. E. **Frames** describes the geology of the Amsterdam Valley. Part of the village of Amsterdam is built on a glacial moraine of undoubted Dwyka structure and age. As had been shown before, a direction of glaciation which resulted in the deposition of the Dwyka is proved to have been from the north. This view has recently received support from the fact that a characteristic porphyritic rock which is found in the conglomerate at Amsterdam has been discovered *in situ* forty miles to the north. A large outcrop of this rock has been discovered on Bonnie Braes farm near Oshoek.

4. *Ueber Untersilur in Venezuela;* von Dr. **Fr. Drevermann.** Neues Jahrb. f. Min., Geol. u. Pal., 1904, pp. 91-93, pl. x.—This little paper is of great interest in that it proves the occurrence of lower Paleozoic deposits on the north side of the Venezuelan-North-Brazilian shield. Engineer Klein, in traveling from Caracas over Valencia to Puerto Cabello, collected a few fossils which Dr. Drevermann thinks are indicative of Lower Silurian age. These specimens are *Calymmene senaria* like those from Cincinnati, Ohio, and *Orthoceras* cf. *olorus* Hall. As no Ordovician formations are known in northern South America the reviewer raised the question—Are these fossils probably of Silurian age? With this in view he addressed the author of the present paper, under date of August 3, 1904, as follows: "The *Calymmene* is nearer to *C. niagarensis* than to *C. senaria* (= *C. callicephala*). . . . As for *Orthoceras* cf. *Volorus* it may be one of several of our Niagaran annulated forms. Its size is so large that I think it rather a Niagaran species.

"On the other hand, in Brazil on the south side of the old land mass there is good Upper Silurian, which as you know was described by Clarke. All in all I feel that the Venezuela fossils are of Upper Silurian age." On October 25 last, Drevermann replied as follows: "I have had another opportunity to compare the *Calymmene* of Venezuela with the North American material kindly sent me by you. An identity with *C. niagarensis* I cannot agree to in spite of the extraordinary similarity heightened by the fact that both examples are preserved in dolomite. The lower lobe of the glabella of the Venezuelan specimen is much larger than in *C. niagarensis* and the latter in this respect reminds one of *C. callicephala* (respectively *C. senaria*). The head of *C. niagarensis* is also considerably more arched. On the other hand, the South American example agrees with *C.*

*niagarensis* in regard to the distance of the facial suture from the posterior margin.

"The certainty that the specimen is of Lower Silurian age is therefore shattered; it may be that it is Upper Silurian and in this case it would be according to your view about Niagara. The Orthoceras is unfortunately not diagnostic." C. S.

5. *Devonian Fauna of Kwataboahegan River;* by WILLIAM ARTHUR PARKS. Rept. Bureau of Mines, 1904, Pt. I, pp. 180–191, pls. 1–8.—This paper is of much importance because it gives one a clear understanding of the facies of the Devonian fauna found on the west side of James Bay, heretofore a rarely visited region. The reviewer has elsewhere discussed this fauna, and before Professor Parks's much larger list was made known (Amer. Geol., Sept., 1903, pp. 153, 154). He then stated that the "fauna as listed by Whiteaves shows unmistakably that their age is about that of the Corniferous (Onondaga)."

The reviewer has enjoyed the privilege of studying the collection belonging to Professor Parks; hence some of the species here cited appear under other names than in the work reviewed. The following list is not complete, only the more significant species being mentioned: *Syringopora nobilis*, *S. perelegans*, *S. hisingeri*, *Diphyphyllum simcoense*, *Phillipsastræa* (?) *gigas*, *P.* (?) *verneuili*, *Crepidophyllum archiaci*, *Favosites basaltica*, *F. hemisphæricus turbinatus*, *Romingeria umbellifera*, *Heliophyllum exiguum*, *Stropheodonta demissa*, *S. crebristriata*, *Strophonella ampla*, *Chonetes lineata*, *Spirifer grieri*, *S. unicus* (the Onondaga form of the Oriskany *S. arenosus*), *Meristella nasuta*, *Atrypa reticularis*, *Amphigenia elongata undulata*, *Conocardium cuneus trigonale*, *Callonema bellatulum*, *Platystoma lineatum*, *Pleurotomaria lucina*, *Bellerophon pelops*, *Orthoceras tantalus*, *O. thoas*, *Calymmene platys*, *Dalmanites archiops*, *D.* (*Synphoria*) *stemmatus* (an Oriskany species), and *Phacops cristata*.

The author states: "It would also appear that the organisms denote an age comparable with the bottom of the Upper Helderberg. In some cases the assemblage would denote the Oriskany." These conclusions are undoubtedly correct, for the Onondaga as seen about Decewville, Ontario, has a large percentage of Oriskany species, but has not *Spirifer unicus.* The latter, however, occurs in the Onondaga not far to the southeast, in Erie county, New York. In general the James Bay Devonian holds the horizon of the Onondaga and has many of the diagnostic species of the Schoharie grit and Onondaga, and at least one of the very characteristic Oriskany brachiopods.

The former conclusion of the reviewer "that the faunal facies is more that of the Mississippian type than any other known" is, through this collection of Professor Parks, brought into closer and more decided harmony with the typical Onondaga of New York. It is clearly established that this fauna did not continue westward into the Manitoba-Athabasca region, as here are known formations somewhat younger, with the *Stringocephalus* fauna of the Euro-Asiatic type. C. S.

6. *Ueber den Bau und die Organisation der Lyttoniidæ Waagen;* by Dr. F. NOETLING. Verh. Deutsch. Zool. Gesellsch., 1904, pp. 103–122.—On the basis of excellent etched material, this author here revises the remarkable brachiopod family Lyttoniidæ, the genera *Oldhamina* and *Lyttonia*, and the species *O. decipiens* and *L. nobilis.* In 1901 Noetling (Neues Jahrb., Beil.-Band xiv, p. 452, foot-note) thought that *Oldhamina* was a "remarkable type of Bryozoa," and because of the similarity of the name to *Oldhamia* he proposed to change it to *Waagenopora.* Under the rules of nomenclature, this change of name can not be made. In the present paper, Noetling says nothing of this proposed name or of his former view as to the nature of these peculiar brachiopods. Other authors have regarded *Oldhamina* as a gastropod and *Lyttonia* as fish teeth, but Noetling's work makes it very clear that we are here dealing with degenerate brachiopods related to *Strophalosia* by the concavo-convex form of the valves and especially by the cardinal process of the dorsal valve, the dental plates, and the fixed or cemented nature of the ventral valve.

The author correctly states that these forms can not be brought into relation with terebratuloid types like *Megathyris*, but does not seem to have noticed the conclusion of Beecher and Schuchert that the affinities of these brachiopods are near the Thecidiidæ as defined by the latter authors—forms closely related to the strophomenoids. Noetling's work makes it now necessary to remove the Lyttoniidæ from the family Thecidiidæ and to associate them as a family with the productoids. The family Lyttoniidæ had its origin probably in *Strophalosia* in Upper Carboniferous time, and is to be regarded as an aberrant and degenerate branch of that genus.

According to Noetling, the great number of so-called "lateral septa" of the ventral valve may be regarded "as supports for the lobes of the dorsal shell," or he thinks "that both median stems of the mantle sinus lay in the space on both sides of the median septum. From the latter came the side branches and continued in form as broad, flat, vascular strands between the lateral lamellæ." The reviewer does not regard these markings as due to the mantle sinus nor as supporting septa, but believes that they are caused by the lobations of the brachia. In the productoids the brachia are in the early ptycholophus or latest schizolophus stage, as may be seen by the reniform markings in many species, yet in the Lyttoniidæ, owing to the progressive elongation of the shell, the brachia are longer and much more numerously lobed, with the lobes directed laterally. Some of this evolution is shown in the oldest *Oldhamina* (?) of the Carnic Alps, described by Schellwien, having but six anteriorly directed lobes; and in the *Keyserlingina* with the same number of laterally directed lobes, recently described by Tschernyschew. In the most recent *Oldhamina* and *Lyttonia*, however, there are from fourteen to forty lobes. The latter represent the highest expression of the ptycholophus stage of brachial development in brachiopods (see Beecher, Bull. U. S. Geol. Surv., No. 87, 1897, p. 108). In the dorsal valve the lobes of the brachia lie between the elevations, while the so-called lateral septa of the ventral valve lie between the recurved bands of each brachial lobe.

Noetling thinks that *Oldhamina* lived with the "dorsal valve directed downward and probably partially buried in the mud." This is an anomalous mode of life for any brachiopod other than *Lingula*. The early cemented condition of these shells indicates that *Oldhamina* lived like other related forms, i. e., with the ventral valve underneath.

The Lyttoniidæ are known in India only in the Upper Permian, i. e., in the Middle or Upper Productus-limestone. They are also known in the Himalaya; at Loping, China; Rikuzen, Japan; near El Paso, Texas, and in Nevada. The occurrence of the older forms has been mentioned above.

Noetling concludes: "Against one's will the impression is made that shortly before extinction the Paleozoic brachiopods once more attained a great development. Probably, however, on account of this accelerated development, they held in themselves the cause for their early extinction, as shown by the aberrant, weak, and possibly even degenerate forms." It is one of the remarkable occurrences that at the close of the Paleozoic, in different stocks of the Strophomenacea, aberrant forms became numerous. These genera are *Keyserlingina*, *Oldhamina*, *Lyttonia*, *Lorzyella*, *Tegulifera*, *Richthofenia*, *Proboscidella*, and *Scacchinella*. C. S.

7. *The Tower of Pelée: New Studies of the Great Volcano of Martinique;* by ANGELO HEILPRIN. Pp. 62, 4to with xxii pls. Philadelphia, 1904 (J. B. Lippincott & Co.).—The results of the studies by the author of the volcanic phenomena of Martinique have already been partly made known in several valuable papers which he has published. The present work contains much interesting descriptive matter and some important suggestions concerning the nature and cause of volcanic action, but its chief interest lies in the description and explanation of the remarkable monolith which rose from the top of Mont Pelée until nearly a thousand feet in height. In spite of repeated shattering and breaking it maintained by constant upward growth a great height for many months before it disappeared. This tower of rock Professor Heilprin regards as the solidified plug of lava filling the conduit of the volcano from a previous active stage which was driven up and out by the renewal of volcanic activity which has recently taken place, and not as the lava of the present epoch, cooling and solidifying as it is forced upward. The facts and arguments favoring this view are presented in detail, since the latter idea has been held by other investigators. The volume is an important and timely contribu-

tion to volcanology and is embellished with many beautiful halftone plates, reproductions of the author's photographs. L. V. P.

8. *Die Jüngeren Gesteine der Ecuatorianischen Ost-Cordillere*, von F. TANNHÄUSER. Wilhelm Reiss, Ecuador, 1870–1874, Petrograph. Untersuch. II, Lief. II, pp. 119–186, 4°, 1904 Berlin. —This is a continuation of the investigation by Reiss of the rocks collected by him in the Andes; this investigation has now been carried on for many years in the mineralogical institute of the University of Berlin under the direction of Professor Klein, as noticed in previous issues of this Journal.

The rocks described are from the Cordillera de Pillaro as far as Sangay, from Azuay and from a part of the Cuenca basin, and comprise the lavas of the great volcanoes of Tunguragua, Altar, Sangay and Azuay. They are nearly all varieties of dacites and andesites whose petrographic characters are given in detail accompanied by a number of analyses. L. V. P.

9. *Die Älteren Gesteine der Ecuatorianischen Ost-Cordillere*, von F. VON WOLFF. Ibidem Lief. III, pp. 189–304, 1904.—In the work mentioned in the foregoing notice only the geologically recent lavas are considered. The petrographic investigation of the region named above is completed in the present memoir, which gives the results of researches made on the older rocks. These comprise gneisses, amphibole schists, diabases in various stages of dynamic metamorphism, mica schists, granites, gabbros, porphyries of various kinds, etc. These have been carefully studied and correlated and in a number of cases analyzed. These two works add much to our knowledge of Andean rocks and petrology. L. V. P.

10. *Ueber die Chemische Zusammensetzung der Eruptivgesteine in den Gebieten von Predazzo und Monzoni*, von J. ROMBERG. Anhang. Abhandl. d. K. Preuss. Ak. Wiss. Jahr, 1904, pp. 135, 4°, Berlin.—In this work the author, in addition to giving a number of new analyses of the rocks of this classic locality, which have been made in connection with his researches by Drs. M. DITTRICH and R. POHL, has assembled all those previously made by other investigators. They are arranged and discussed according to the chemical classification proposed by Osann. The recent work of other geologists in this region is also taken up and critically examined and many dissenting opinions expressed. The new analyses have evidently been well and carefully executed and add much information to our knowledge of this complex and interesting group of igneous rocks. L. V. P.

11. *Heptorit, ein-hauyn-monchiquit aus dem Siebengebirge am Rhein*, von K. BUSZ. Neues Jahrb. f. Min., Bd. II, 1904, pp. 86–92.—This new variety of monchiquite occurs as a narrow dike on the boundary between trachyte and Devonian graywackes and in the hand specimen appears like a fine-grained basalt. The microscope shows it to consist of basaltic augite, a relatively large amount of brown hornblende in fine needles and well crystallized violet-blue hauynite. These minerals lie in a colorless

base which is assumed to be glass ; whether it may not be wholly or in part analcite is not mentioned. Occasional laths of labradorite also occur and in places the rock holds the large masses of olivine often seen in basaltic rocks. An analysis gave the following results :

| $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $FeO$ | $CaO$ | $MgO$ | $Na_2O$ | $K_2O$ | $H_2O$ | $SO_3$ | $P_2O_5$ | $Cl$ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43·92 | 1·78 | 17·62 | 4·05 | 3·94 | 13·07 | 8·16 | 2·84 | 1·33 | 2·82 | 0·47 | 0·15 | 0·22 | = 100·37 |

This appears to be a well-defined type of this small but interesting group of igneous rocks. The name is the translation into Greek of the Siebengebirge where it occurs. L. V. P.

12. *Die Kristallinen Schiefer*, I, *Allgemeiner Theil*, von U. GRUBENMANN. Pp. 101, 8vo, 2 pls. 1904, Berlin (Bornträger Pub.)—The author states that this work, which is a summation of his lecture course upon this subject, is an attempt to explain in accordance with physical and chemical principles the origin and characteristic properties of the crystalline schists. He begins with a description of the material from which the schists are formed, giving the origin and characters of the sedimentary and igneous rocks, so far as these pertain to the subject. Next the various factors of metamorphism are dealt with, the effects of solutions, of high temperatures, of pressure, etc. After this the results of these agencies in the production of different minerals, structures, textures, etc.; are discussed and the work concludes with a short, general account of the geological occurrence of the crystalline schists. It is clearly and simply written and the student and teacher of petrography will find much in it that is interesting and suggestive. It is inferred from the scope and title of the book that it is only the introductory portion of a larger descriptive work. L. V. P.

13. *Yttrium and Ytterbium in Fluorite.*—W. J. HUMPHREYS, as the result of a spectroscopic examination of samples of fluorite from many localities in all parts of the world, shows that the rare element yttrium is distinctly present in most cases while a considerable number contain also ytterbium. The specimens found to be richest in these elements were from Amelia Court House, Virginia, Llano County, Texas and Corocoro, Bolivia. The two localities first mentioned afford a number of rare mineral species which were also found to contain yttrium and often in addition ytterbium. It is interesting to note that the three samples mentioned proved to be exceptionally sensitive to the effect of heat in producing phosphorescence ; as noted by the author some years since, a fluorite from Amelia Court House became luminous simply from being held in the hand for a few minutes.—*Astrophys. Journal*, xx, 266.

14. *Hamlinite from Brazil.*—The rare mineral species hamlinite, thus far only known from Maine, as described by Penfield, has been identified by Hussak in the diamond-bearing sands of the Serra de Congonhas, Diamantina, Brazil. It occurs sparingly

in colorless to rose-red or yellow crystal and cleavage fragments: the faces *c*, *r* and *f* were identified and the angles found to agree with the measurements of Penfield. The specific gravity is 3·254 to 3·281. A qualitative examination by Florence proved the Brazilian mineral to be a hydrophosphate of aluminium and strontium without barium or fluorine, but probably containing a small amount (2 p. c.) of alkalies.—*Ann. Nat. Hofmuseums*, xix, 93, 1904.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Publications of the Yale Observatory.*—The Yale Observatory has recently issued a Report of the Director, Dr. W. L. Elkin, for the years 1900–1904. In regard to the work of 1903–1904, he states: "During the past year the heliometer has been in active operation, Dr. Chase having devoted himself with great energy and self-sacrifice to the completion of the stellar parallax research we have been engaged upon for the past ten years. This now may be said to have finally reached a point where the observations may be suspended and our energies entirely given to their reduction. Mr. Smith has completed the new series on the parallax of Arcturus and has begun a series on the parallax of the Pleiades.

The meteor apparatus was put in use during the November epoch and a few trails secured. Dr. Max Wolf of Heidelberg, Germany, has kindly forwarded to us his meteor photographic trails of the Perseid epoch and those which seem to be true Perseids have been measured by Miss Palmer. Miss Palmer and Miss Newton are still employed on the index catalogue to the Bonn Durchmusterung. The time service has been maintained efficiently by Messrs. Chase and Smith."

The concluding portion of Volume I of the *Transactions* has also been published. This includes the Preface and Parts VII and VIII, pp. 335–390. These parts are devoted to a Revision of the first Yale triangulation of the principal stars in the group of the Pleiades by Dr. W. L. Elkin; and a second Determination of the relative position of the principal stars in the group of the Pleiades by Mason F. Smith.

2. *Publications of the Yerkes Observatory, Vol. II, 1903.* Chicago, 1904 (University of Chicago Press).—This volume, also issued as Vol. VIII of the first Series of the Decennial Publications of the University, contains a series of seven articles, on work done at the Yerkes Observatory; their titles are as follows: Measures of double stars in 1900 and 1901, by S. W. Burnham; micrometrical observations of Eros during the opposition of 1900–1901, by E. E. Barnard; recent rigorous methods of treating problems in celestial mechanics, by F. R. Moulton; radial velocities of twenty stars having spectra of the Orion type, by E. B. Frost; spectra of stars of Secchi's 4th type, by G. E. Hale, F. Ellerman and J. A. Parkhurst; astronomical photography with

the forty-inch refractor and two-foot reflector, by G. W. Ritchey, accompanied by 26 plates, giving beautiful photographs of the moon's surface, star clusters, nebulæ, and other points; and lastly, the orbit of the minor planet (334) by Kurt Laves.

3. *How to Know the Starry Heavens, a Study of Suns and Worlds;* by EDWARD IRVING. Pp. xvi, 313, with charts, colored plates, diagrams, etc. New York, 1904 (Frederick A. Stokes Co.). —The present volume is one of a series planned by the author which are to deal with the sciences of Astronomy, Geology, Biology and Sociology. It is a very liberally illustrated account of the celestial universe, with the subjects presented in clear, popular, and often colloquial style, which must certainly appeal to the class of readers for which it is intended. Some of the word-illustrations introduced are novel and ingenious, and will help to an understanding of a somewhat difficult subject. The next volume to appear will deal with the earth, from its nebulous birth to the advent of man, and will be entitled: "How to Know the Earth's History."

4. *The Jefferis Mineral Collection.*—It is announced that the Carnegie Museum, Pittsburg, Pa., has purchased the Jefferis collection of minerals; it is to be known in perpetuity as "The W. W. Jefferis Mineral Collection of the Carnegie Museum." It owes its existence to the active work and liberal expenditure by Mr. Jefferis begun some seventy years ago, and now ranks as one of the finest private collections of minerals in America. Living in West Chester, Chester county, Pa., he had unusual opportunities of collecting choice specimens from the ancient gneisses, serpentines and limestones, as well as from the trap rocks of eastern Pennsylvania, New Jersey and New York. He also visited northern New York, Canada and Europe; and carried on extensive exchanges with other collectors all over the world.

Mr. Jefferis, although primarily a collector, was also a discoverer and contributor to science. A number of new minerals were discovered by him and in addition he aided largely in extending the distribution of known minerals and in furnishing material for the reëxamination of old or poorly known ones. Dana drew largely from Mr. Jefferis' notes and specimens, some of which were figured in his "System of Mineralogy"; Genth's "Mineralogy of Pennsylvania" was also indebted to Mr. Jefferis' labors in the field.

5. *The Chemical Engineer.* — A new monthly journal of practical, applied and analytical chemistry was started in November, 1904, under the above title. It is published by The Chemical Engineer Company, Allentown, Pa., at $3 a year. The first number contains articles on the Valuation of Coal for Steaming Purposes, on Tests for Wood Paving, with others on subjects less directly technical.

## OBITUARY.

DR. BENJAMIN W. FRAZIER, Professor of Mineralogy and Metallurgy at Lehigh University, Bethlehem, Penn., died on January 4 at the age of sixty-three years.

THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. XIV.—*On the Optical Constants of the Human Eye for different Colors;* by CHARLES S. HASTINGS.

A COMPLETE determination of the optical constants of the human eye for all conditions of accommodation and for all colors is yet wanting in the literature of physiological optics. Indeed, the only addition to the knowledge possessed by Helmholtz and published in his famous Physiologische Optik nearly forty years ago, consists in a slight change in his assumptions as to the dimensions of the schematic eye and a calculation of its cardinal points when accommodated for a near object.*

A necessary use for a larger knowledge recalled to my mind a series of observations made several years ago for a different purpose, but which would clearly yield the required information. These observations are contained in the following table, in which the first column contains the Fraunhofer line which defines the kind of light observed; the columns headed N and F, respectively, the nearest and farthest distances, in inches, at which I could see distinctly the spectral line; the column under $-c$ is the mean of the reciprocals of N and F, and the last column the difference of these reciprocals.

| Line | N | 1/N | F | 1/F | $-c$ | 1/A |
|---|---|---|---|---|---|---|
| A | 15·75 | ·06349 | 18·00 | ·05556 | ·05952 | ·00793 |
| D | 12·60 | ·07937 | 13·80 | ·07246 | ·07592 | ·00691 |
| F | 10·40 | ·09615 | 11·25 | ·08889 | ·09252 | ·00726 |
| G | 8·60 | ·11628 | 9·50 | ·10526 | ·11072 | ·01102 |
| H.K | 7·25 | ·13793 | 8·50 | ·11765 | ·12779 | [·02028] |

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* It should be noted that W. Einthoven computed the constants for two different refrangibilities, namely, for that of the Fraunhofer D and F lines, for a schematic eye adjusted for great distance; but his assumption that the dispersive power is very nearly as great as that of dense flint glass makes them unavailable. A possible missprint renders two of the constants erroneous. See Pflüger Archiv. f. Physiol., lxii, 166.

The last column headed 1/A is the well known Donders constant of accommodation. This should be nearly constant for all wave-lengths of light. Neglecting the last value, which is sure to be greatly in excess on account of unavoidable errors due to fluorescence of media of the eye impairing the precision of vision in this region of the spectrum, the mean value of the accommodation constant is ·00825/1 in. With this value of the constant of accommodation and an assumed accuracy of the values of *c*, the calculated values of the far and near points are as follows:

| | N′ | F′ |
|---|---|---|
| A ............ | 15·71 | 18·06 |
| D............. | 12·50 | 13·94 |
| F............. | 10·35 | 11·31 |
| G............. | 8·70 | 9·38 |
| H.K .......... | 7·58 | 8·09 |

The errors implied in the observations of the extreme violet light are just such as we should expect from the imperfect vision in this region of the spectrum due to fluorescence. If we assume that the differences for the other wave-lengths are due to errors of observation only, we find that the probable error of a single measurement is ± 0·067 of an inch. As the measurements seem to have aimed at a precision not much greater than 0·1 of an inch, the accordance must be regarded as very satisfactory.

As to the precision with which *c* is determined, for it is the variation of this quantity which yields the physical constant desired, we have the following test. It is known that the media of the eye have dispersive powers not differing in kind from that of other colorless media, hence the differential refractive power of the eye ought to be expressible as a linear function of the indices of refraction of such substances, water for example. Thus, from the following data,

| | $C_A - C$ | $n - n_A$ |
|---|---|---|
| A........... | ·00000 | ·00000 |
| D........... | ·01640 | ·00365 |
| F........... | ·03300 | ·00788 |
| G .......... | ·05125 | ·01135 |
| H.K ........ | ·06827 | ·01424 |

I find,

$$c_A - c = (4{\cdot}50 \pm {\cdot}08)\,(n - n_A)\ 1\,/\,1 \text{ inch.}$$

In this result the observation on extreme violet light is included. The general conclusion, when the centimeter is chosen as the unit of length, may be written

$$\delta c\,/\,\delta n = 1{\cdot}77\,/\,1^{\text{cm}}$$

where $\delta n$ indicates the variation of index of refraction of water.

The results given above must be regarded as very accurate for the myopic eye studied, but it is not quite obvious how they should be employed as a basis for estimating the dispersive power of the average human eye, which may be supposed to be accurately equivalent to the schematic eye described in Helmholtz.* It seems probable, however, that the assumption that such an eye would possess the same differential power for different wave-lengths of light will prove not far from the truth. Under these conditions, since it is known that the dispersive powers of the aqueous and vitreous humors are the same as that of water, it is possible to calculate the virtual dispersive power of the lens of the eye, and it is found that we must assume a dispersive power in the lens of the schematic eye about half way between that possessed by ordinary crown glass and by dense flint glass, or, quite accurately, that of turpentine. If it were supposed that the eye examined differed from the schematic eye only in having a thicker lens, this value would be somewhat smaller. A discussion of known facts bearing on this point will appear at the end of the article.

We are now in a position to calculate all the cardinal points of the schematic eye for all accommodations and for all wave-lengths, but as these values cannot be given as linear functions of the variables, it is more useful to arrange a sufficient number in tables so that any required value can be found by proper interpolation. As a basis of the computations I adopt, after Helmholtz, as the mean refractive index of the aqueous and vitreous humors, $n_0 = 1{\cdot}3365$, and as that of the lens, $n'_0 = 1{\cdot}4371$. Also, the radii of the cornea, the front surface of the lens, and the back surface, are, respectively, 0·728, 1·000, and 0·600 centimeters. Finally, the dispersive power of the two humors being equal to that of water, we have:

| | A | B | C | D |
|---|---|---|---|---|
| $n - n_0$ | −·00558 | −·00446 | −·00370 | −·00183 |

| E | F | G | H |
|---|---|---|---|
| +·00045 | +·00241 | +·00590 | +·00900 |

while, to meet the measured chromatic error of the eye as determined above,

$$\delta n'/\delta n = 1{\cdot}57.$$

With these data I have computed the following tables. The values of $c'$ in both tables are the reciprocals of the distance

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* See Helmholtz, Physiologische Optik, 2te Auflage s. 140.

TABLE I.

| Curvature of incident wave-surface | | $c' = \cdot0000$ | $c' = -0\cdot0100$ | $c' = -0\cdot0330$ | $c' = -0\ 066$ |
|---|---|---|---|---|---|
| | | $x$ | $\delta x$ | | |
| Curvature of the cornea | $\gamma$ | 1·2773 | | | |
| Curvature of the first lens surface | $\gamma'$ | 1·0000 | ·1043 | ·3433 | ·6690 |
| Curvature of the second lens surface | $\gamma''$ | −1·6667 | −·0239 | −·0746 | −·1520 |
| Distance from vertex of cornea | | | | | |
| to first lens surface | $d$ | ·360 | −·0060 | −·0200 | −·0400 |
| to second lens surface | $d'$ | ·720 | | | |
| to first principle focus | $F_1$ | −1·3744 | ·0279 | ·0873 | ·1618 |
| to second principle focus | $F_2$ | 2·2823 | −·0316 | −·0995 | −·1876 |
| to first principle point | $p_1$ | ·1753 | ·0021 | ·0063 | ·0105 |
| to second principle point | $p_2$ | ·2110 | ·0029 | ·0087 | ·0146 |
| to first nodal point | $n_1$ | ·6969 | −·0066 | −·0210 | −·0404 |
| to second nodal point | $n_2$ | ·7325 | −·0057 | −·0186 | −·0363 |

of distinct vision measured from the vertex of the cornea, which is taken as the origin of abscissas. The curvature of the cornea and the position of the second vertex of the lens are invariable.

For the chromatic differences for these constants we find the following table:

TABLE II.

$\delta x/\delta n$

| $x$ | $c' = \cdot0000$ | $c' = -\cdot0100$ | $c' = -\cdot0330$ | $c' = -\cdot0660$ |
|---|---|---|---|---|
| $F_1$ | +5·660 | +5·593 | +5·464 | +5·283 |
| $F_2$ | −5·504 | −5·448 | −5·342 | −5·182 |
| $p_1$ | +0·175 | +0·167 | +0·158 | +0·152 |
| $p_2$ | +0·335 | +0·335 | +0·331 | +0·329 |
| $n_1$ | −0·179 | −0·190 | −0·211 | −0·228 |
| $n_2$ | −0·019 | −0·022 | −0·038 | −0·051 |

With these two tables it is easy to solve all problems connected with the purely optical properties of the schematic eye. We may, for example, employ them for comparing the performance of the model with any recorded observation on real eyes. Thus Helmholtz (page 158) states that for his eye the difference of accommodation for red (C) and violet (G) light was ·0167, in the units employed in the tables, while Fraunhofer, who gave the first recorded measures involving this magnitude, found a value included between ·0154 and ·0205. The schematic eye as described in this paper demands ·0167.

After all the above calculations were concluded I found a series of observations on his own eye by Max Wolf* which might have been used as well as the ones given above. His method was to observe a small globule of mercury, strongly illuminated by sunlight, through a prismatic ocular and find the displacement of the globule when sharp definition of the spectrum was secured at different Fraunhofer lines. These observations are by no means easy, but they were carried out with remarkable skill so that the means of four series gave, after eliminating the dispersion due to the lens of the ocular, a result of exactly the same degree of precision as my own. Professor Wolf made no other use of his results than to prove that the human eye has notably greater dispersion than the reduced eye of Listing which is supposed to be made of pure water; but a reduction of them after the method in which mine were treated, when corrected for the slight degree of hypermetropy possessed by his eye, gave $^{\delta n'}/_{\delta n}$ equal to 1·523. In view of this fact I should prefer 1·54 as a definitive value were so small a change really worth while. Since the last value only differs from that employed by an amount equal to the probable error attaching to it, we may, I think, accept the results given above with considerable confidence.

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* Annalen d. Physik u. Chemie, xxxiii, 1888.

**Yale University, January, 1905.**

## ART. XV. — *Notice of the Discovery of a New Dike at Ithaca, N. Y.*;[*] by V. H. BARNETT.

THE occurrence of several dikes of igneous rock cutting the Devonian shales and sandstones near Ithaca, N. Y., was recognized as early as 1842. Vanuxem[†] records in his report on the 3d District, the presence of four small dikes near Ludlowville. Other small dikes, which were discovered by students and professors of Cornell University, were described in a paper by Prof. Kemp,[‡] in 1891. This paper is the latest published statement, so far as the writer knows, concerning the dikes at Ithaca. According to Prof. Kemp, four dikes were then known in the vicinity of Ithaca in addition to those recorded by Vanuxem. Kemp was able to relocate but two of Vanuxem's dikes, so that the total number then known was six.

During the past season the writer, engaged as a field assistant on the U. S. Geological Survey, discovered in connection with Dr. E. M. Kindle a number of hitherto unknown dikes in the vicinity of Ithaca. Most of these dikes, like those previously known at Ithaca, are thin sheets of peridotite generally from one to five inches in width. The total number of dikes now known to the writer near Ithaca exceed twenty-five.

One of the newly discovered dikes is of such unusual size for this region as to justify a brief preliminary notice. It is exposed in a small ravine on the west side of Lake Cayuga about one mile south of Glenwood. The dike is of light greenish gray color with numerous inclusions of shale and small limestone fragments. The latter are probably derived from the Tully limestone, which is some 450 feet below the outcrop. The numerous included fragments give the mass a breccia-like appearance. The direction is nearly north and south, but the contact is irregular and clearly shown on the east side, where the shale is considerably baked. On the west side the dike passes under a mass of drift so that the total width is not known. It is, however, not less than 25 feet thick. Another dike mass, 13 feet in width, lies 150 feet to the west of the one just described and is identical with it in appearance. The latter terminates abruptly on the west along a joint plane of the shale, and passes under the drift on the east. The relations of the two masses suggest that they may represent a single dike considerably more than 100 feet in width which pinches out both north and south. In Indian Creek, about three-quarters mile south of this outcrop, is a two foot dike and in Glenwood Creek, to the north, a dike eight feet wide occurs.

Ithaca, N. Y., January 24.

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[*] Published by permission of the Director of the U. S. Geological Survey.

[†] Rep. 3d Dist. N. Y. State Geological Survey, p. 169.

[‡] This Journal (3), vol. xlii, pp. 410-412, 1891.

## Art. XVI.—*Dumortierite*; by Waldemar T. Schaller, U. S. Geol. Survey.

The following paper* is an excerpt of a paper on dumortierite to appear in a forthcoming bulletin of the U. S. Geol. Survey.

The description is mainly of the lavender California dumortierite and also of the Washington mineral. Several imperfect crystals—two from California, one from Arizona and three from New York—were found and some crystallographic data obtained.

The California dumortierite occurs in a dike, a few miles east of Dehesa, San Diego Co. The dike is in a disintegrated biotite granite and has a length of about 1000 feet with a thickness of from 30 to 40 feet and strikes S. 70° E., with a dip of 70° N. 20° E. The upper part of the dike is a fine-grained rock consisting of quartz and sillimanite, while the lower part is a coarse rock composed of quartz and dumortierite, the latter in radiating masses several centimeters thick. They show a transverse parting fairly well developed: the color of the mineral is lavender instead of blue; the pleochroism is from colorless to red-purple.

A number of thin sections of the dumortierite rock were prepared and studied with the following results.

Microscopically the minerals present in the lower part of the dike are seen to be dumortierite and quartz with muscovite and sillimanite in small quantities, together with accessory magnetite, titanite, rutile (?), apatite and zircon, with a number of small undetermined inclusions. The dumortierite occurs in irregular masses with ragged outline, and also in fan-shaped radiating masses sometimes of large size. Irregular broken fibrous masses also occur scattered through the slide. The quartz is allotriomorphic and is but slightly cracked. It is rather full of inclusions in places. With the exception of a little muscovite, there are no secondary minerals present.

The common form for the dumortierite is the radiated fan-like masses that vary considerably in size. When the entire piece is larger than a quadrant, parts of the black cross (seen in spherulites) are seen when the nicols are crossed. These fan-shaped pieces are probably the results of an incomplete spherulitic growth. The most perfect one consisted of but half a circle. On certain parts no radiated fibers are detectable, the (prismatic) cleavage lines being perfectly parallel. Some of the pieces become decidedly fibrous towards the ends and the various individual fibers depart somewhat from true parallelism. In between these fibers, fine-grained aggregates of muscovite can often be seen.

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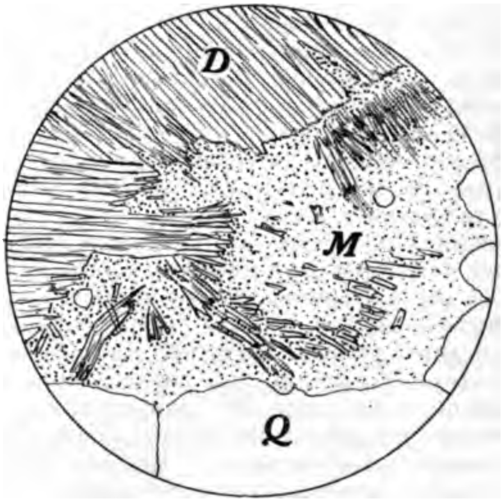
On a number of pieces a (secondary?) growth of fibers was seen which are probably in all cases dumortierite, as with high powers a faint pleochroism can be detected. They were at first thought to be sillimanite, but they agree in all their properties as far as can be determined with dumortierite. These fibers can be classed in two parts.

In the first part belong those which seem to have formed, as a secondary growth, on the main masses of dumortierite. The fibers branch out considerably and often form a radiating fringe around an entire section of the mineral. They penetrate the quartz grains and interstitial muscovite is absent. The line where they join on to the main mass of the mineral is usually fairly well defined. In general, the fibers are normal to the edge of the main mass, but locally they vary considerably at times, especially where they form fan-like groups.

1



The second class is clearly a stage in the alteration of the dumortierite to muscovite. The solid mass of dumortierite becomes fibrous and, at the edge breaks up into small fibers which gradually become loose from the parent mass. The space where they formerly joined is now occupied by a granular mass of muscovite which also fills the spaces between the fibers. Gradually this process goes on till finally we have a large mass of granular muscovite, in which are imbedded a few fibrous prisms of the original mineral. Fig. 1 shows diagrammatically a stage in the process.

Basal sections present an entirely different appearance. The macropinacoidal cleavage, so well developed on the New York mineral, does not show on the sections of the California mineral.

The imperfect prismatic cleavage is present and divides the section up into a multitude of irregular bodies. Occasionally a short crack is observed which is parallel to the brachypinacoid, and it may be that the mineral possesses an imperfect interrupted brachypinacoidal cleavage.

The prismatic cleavage was found to be parallel to the prism (210). A large number of measurements gave as the angle (010): cleavage cracks 62°–67°, averaging 64°–65°. The angle (010): (120) is 65° 23′. The cleavage cracks are irregular and it was difficult to obtain any accurate measurements, but the ones made are sufficient to determine the cleavage. They were measured against the trace of the optic axial plane (= (010)).

Polysynthetic twinning lamellæ were observed a number of times and in one particular section (the same on which the prismatic cleavage was measured) were determinable to a certain extent. The alternate lamellæ extinguished together, the difference in angle of extinction of two adjacent lamellæ being 31°. The line joining these lamellæ is parallel to the cleavage or to the prism (210).

The pleochroism of the mineral is beautiful, especially if the section be not too thin. $\mathfrak{c} = a$ is colorless, $\mathfrak{b} = b$ is colorless to very faint pink, $\mathfrak{a} = c$ is deep red purple. None of the sections entirely possess the ordinary blue pleochroism. In some slides, however, there are certain small areas of varied and irregular shape which do show the ordinary pleochroism. These small blue areas in the rich red-purple background make a most beautiful combination. On some sections a large area will have a faint bluish purple color, as if intermediate between the deep blue and the red-purple.

The axial angle on the California dumortierite is small. The following measurements were made with the microscope and micrometer ocular and represent only approximate values.

$$2E_{Li} = 33^\circ$$
$$2E_{Na} = 37^\circ$$
$$2E_{Cu} = 42^\circ$$

The dispersion is $\rho < v$.

The dumortierite from Skamania Co., Washington, was first described by Ford.* Mr. Brereton, of Woodstock, Oregon, kindly sent the writer some specimens on which the following description is based.

The rock is a light-colored fine-grained one, composed of about equal parts of andalusite, quartz and muscovite (determined in thin section).

The dumortierite occurs in small spherulites scattered throughout the rock and occasionally bunched together to form a large patch of blue. On an average they reach a diameter of from ½ to 1$^{mm}$. Their shape, while in general circular, is often elliptical and may become very irregular in places. The spherulites consist of fibers radially arranged and show all the optical phenomena of "spherulites." The dumortierite has parallel extinction and its birefringence is somewhat higher than that of the quartz and also slightly more than that of the andalusite, though the difference between that of the latter two minerals is very small.

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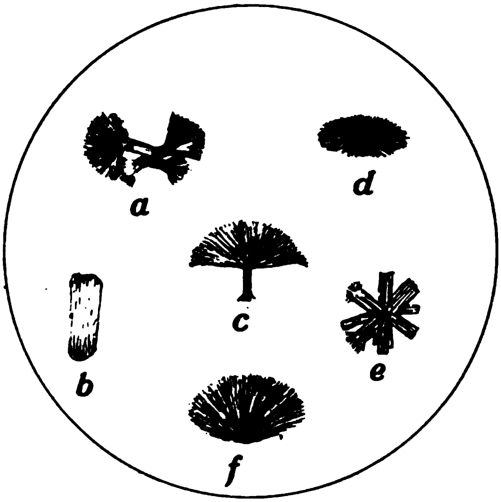
* This Journal (4), xiv, 426.

The intensity of the pleochroism of the dumortierite varies so that in some spherules there are concentric bands of fibers varying greatly in the intensity of their color. Some are almost colorless, and it was at first thought they might be parallel growths of andalusite with the dumortierite, but such a conclusion could not be verified.

2



The fibers are not always perfectly radial. They are at times gathered into "brushes" and a number of these put together may form a spherulite. The fibers are thus more thickly crowded in places than elsewhere, and this frequently results in intensifying the pleochroism, so that in some spherulites there are numerous blotches of blue much deeper colored than the rest. Muscovite is frequently abundant in a spherulite, being formed between the fibers, and is probably an alteration product of the dumortierite. Frequently a mass of dumortierite will be almost completely changed to mica, leaving but small fragments of the original mineral behind.

The fibers of dumortierite, while usually arranged radially, sometimes assume different shapes, and some of the masses of dumortierite seen under the microscope are reproduced in fig. 2.

Fig. 2 shows variations from typical spherulitic form that the fibers of dumortierite assume. *a* is four prisms irregularly joined at the center, the ends spreading out into "brushes" of fine fibers. This form is fairly abundant. *b* forms a prismatic portion becoming fibrous at both ends, and while common in the New York, Arizona, and California occurrences is a rare type for Washington dumortierite. *c* forms a sort of fan and is composed of several "brushes" joined together. It is a common type. *d* is an elliptical spherulite. *e* is a mass of prisms such as *b* but not spreading out as *a* does. It is of rarer occurrence. *f* is a bunch of radial fibers with no prismatic stem as in *c*. It is fairly common.

### *Crystallographic.*

The mineral is orthorhombic and from the various measurements the following axial elements have been calculated:

$a = {\cdot}8897 \qquad c = {\cdot}6871$

The crystals were measured with the two-circle goniometer, and the values for $p_0$ and $q_0$, from which the above ratios are obtained, are:

$p_0 = {\cdot}7723 \qquad q_0 = {\cdot}6871$

The forms observed are as follows:

$b = 0\,\infty = 010$
$a = \infty\,0 = 100$
$l = \infty\,2 = 120$
$m = \infty = 110$
$g = \frac{3}{2}\,\infty = 320$
$n = 2\,\infty = 210$
$d = \frac{1}{2}\,0 = 102$
$v = \frac{2}{3}\,0 = 203$

Besides these forms, reflections were obtained from several other minute faces, but they were so minute and the reflections so poor that their validity is very questionable and they are omitted from the foregoing list. The average of the measured angles compared with the calculated values are shown in the following table:

| Letter. | Symbol. | Measured. | | Calculated. | |
|---|---|---|---|---|---|
| | | $\phi$ | $\rho$ | $\phi$ | $\rho$ |
| *b* | $0\,\infty = 010$ | 0° 00′ | 90° 90′ | 0° 00′ | 90° 00′ |
| *a* | $\infty\,0 = 100$ | 91 23 | " | 90 00 | " |
| *l* | $\infty\,2 = 120$ | 29 19 | " | 29 20 | " |
| *m* | $\infty = 110$ | 49 01 | " | 48 20 | " |
| *g* | $\frac{3}{2}\,\infty = 320$ | 59 49 | " | 59 19 | " |
| *n* | $2\,\infty = 210$ | 65 23 | " | 66 01 | " |
| *d* | $\frac{1}{2}\,0 = 102$ | 91 21 | 21 46 | 90 00 | 21 07 |
| *v* | $\frac{2}{3}\,0 = 203$ | 87 39 | 26 58 | " | 27 14 |

The brachypinacoid is present on four crystals, usually as broad faces. Some give relatively good reflections.

The macropinacoid occurs on all the crystals except the one from Arizona. The reflections were poor but serve to identify the form. The $\phi$ angles measured are as follows:

| | | |
|---|---|---|
| 90° 02′ | (Cal.) | Calc. 90° 00′ |
| 93 46 | “ | |
| 90 00 | “ | |
| 92 57 | (N. Y.) | |
| 91 15 | “ | |
| 90 16 | “ | |

The brachyprism $l = \infty 2 = 120$ occurs on four crystals, giving fair reflections.

| | | | |
|---|---|---|---|
| Meas. ($\phi$) | 30° 00′ | (Cal.) | Calc. ($\phi$) 29° 20′ |
| | 28 00 | “ | |
| | 29 22 | “ | |
| | 29 34 | (N. Y.) | |
| | 29 39 | “ | |

The unit prism is poorly developed on the California crystals, being present but once as a narrow face giving a poor reflection. On the Arizona crystal it occurs twice as broad faces.

| | | | |
|---|---|---|---|
| Meas. ($\phi$) | 48° 52′ | (Cal.) | Calc. ($\phi$) 48° 20′ |
| | 49 16 | (Ariz.) | |

The macroprism $g = \frac{3}{2}\infty = 320$ is present several times on all the crystals except the one from Arizona. The measured angles vary somewhat.

| | | | |
|---|---|---|---|
| Meas. ($\phi$) | 58° 55′ | (Cal.) | Calc. ($\phi$) 59° 19′ |
| | 59 42 | “ | |
| | 60 36 | “ | |
| | 59 38 | “ | |
| | 59 23 | “ | |
| | 60 14 | “ | |
| | 59 04 | (N. Y.) | |
| | 60 07 | “ | |
| | 59 25 | “ | |
| | 60 23 | “ | |
| | 60 31 | “ | |

The macroprism $n = 2\infty = 210$ is present four times. The reflections were fair.

| | | | |
|---|---|---|---|
| Meas. ($\phi$) | 65° 26′ | (Cal.) | Calc. ($\phi$) 66° 01′ |
| | 65 35 | “ | |
| | 65 19 | “ | |
| | 65 12 | “ | |

The macrodome $d = \frac{1}{2} 0 = 102$ is present once on the Arizona crystal. The reflections were not very good. The dome $v = \frac{2}{3} 0 = 203$ is present on one of the California crystals. The face is exceedingly minute and is not shown in the drawing, fig. 3, A, and the reflection was poor.

On crystal No. 4 (N. Y.) were observed two very small faces, giving poor reflections.

| | $\phi$ | $\rho$ |
|---|---|---|
| (1) | 83° 46′ | 17° 54′ |
| | 83 16 | 17 44 |
| (2) | 80 19 | 16 50 |
| | 84 17 | 17 28 |

These agree approximately with the symbol {8. 1. 20} or considering the form vicinal to a dome, to {205}.

The following table gives the calculation of the forms of dumortierite based on the elements given in this paper. The table corresponds to those given in Goldschmidt's Winkeltabellen.

| | | | | | |
|---|---|---|---|---|---|
| = ·8897 | $lga = 9{\cdot}94924$ | $lga_0 = 0{\cdot}11202$ | $lgb_0 = 9{\cdot}88779$ | $a_0 = 1{\cdot}2943$ | $p_0 = {\cdot}7723$ |
| = ·6871 | $lgc = 9{\cdot}83702$ | $lgb_0 = 0{\cdot}16298$ | $lgq_0 = 9{\cdot}83702$ | $b_0 = 1{\cdot}4554$ | $q_0 = {\cdot}6871$ |

| o. | Letter | Sym. Gdt | Sym. Miller | $\phi$ | $\rho$ | $\xi_0$ | $\eta_0$ | $\xi$ | $n$ | $\chi$ (Prism) $x:y$ | $y$ | $d = tg\,\rho$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *b* | $0\infty$ | 010 | 0° 00′ | 90° 00′ | 0° 00′ | 90° 00′ | 0° 00′ | 90° 00′ | 0 | ∞ | ∞ |
| 2 | *a* | $\infty 0$ | 100 | 90 00 | " | 90 00 | 0 00 | 90 00 | 0 00 | ∞ | 0 | " |
| 3 | *l* | $\infty 2$ | 120 | 29 07 | " | " | 90 00 | 29 07 | 60 53 | ·5570 | ∞ | " |
| 4 | *m* | $\infty$ | 110 | 49 01 | " | " | " | 49 01 | 40 59 | 1·1510 | " | " |
| 5 | *g* | $\frac{3}{2}\infty$ | 320 | 59 47 | " | " | " | 59 47 | 30 13 | 1·7170 | " | " |
| 6 | *n* | $2\infty$ | 210 | 65 23 | " | " | " | 65 23 | 24 37 | 2·1825 | " | " |
| 7 | *d* | $\frac{1}{2}0$ | 102 | 90 00 | 21 07 | 21 07 | 0 00 | 21 07 | 0 00 | ·3862 | 0 | ·3862 |
| 8 | *v* | $\frac{2}{3}0$ | 203 | " | 27 14 | 27 14 | " | 27 14 | " | ·5147 | 0 | ·5147 |

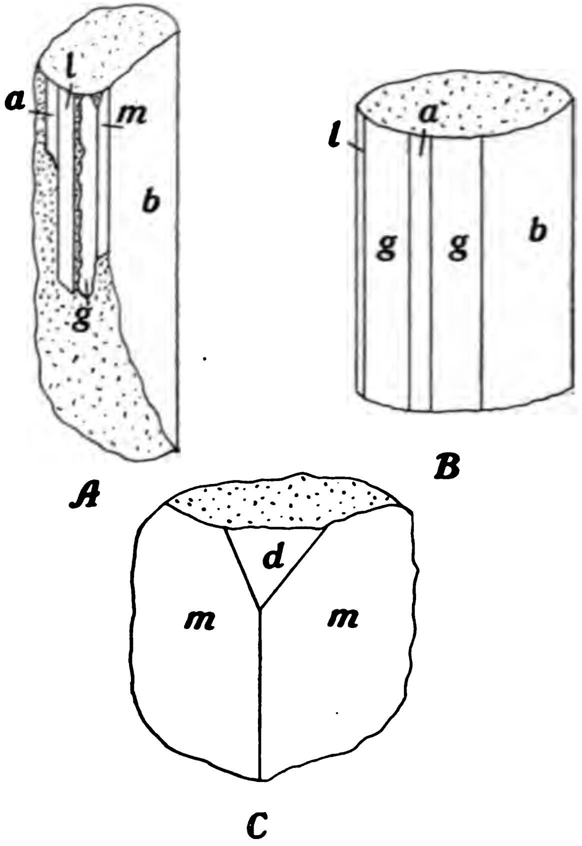
The combination seen on the six crystals measured are:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. 1 | Cal. | *b*, | *a*, | *l*, | *m*, | *g*, | *n*, | —, | *v*, |
| " 2 | " | *b*, | *a*, | *l*, | —, | *g*, | *n*, | —, | —, |
| " 3 | Ariz. | —, | —, | —, | *m*, | —, | —, | *d*, | —, |
| " 4 | N. Y. | *b*, | *a*, | —, | —, | *g*, | —, | —, | —, |
| " 5 | " | *b*, | *a*, | *l*, | —, | *g*, | —, | —, | —, |
| " 6 | " | —, | *a*, | *l*, | —, | *g*, | —, | —, | —, |

**Fig. 3 shows three of the crystals.**

**A is from California, size 1$^{mm}$ × ¼$^{mm}$.**
**B " New York, about 1$^{mm}$ × ½$^{mm}$.**
**C " Arizona, about 1$^{mm}$ × 1$^{mm}$.**

3



The minerals andalusite, sillimanite, staurolite and dumortierite possess certain properties that are very similar. They are all orthorhombic, their axial ratios are similar, their principal constituents are silica and alumina, and in many ways these minerals can well be grouped together. A comparison of their axial ratios is given below:

| | *a* | *c* |
|---|---|---|
| Adalusite .......... | ·9861 | ·7025 |
| Sillimanite ......... | ·970 | ? |
| Staurolite .......... | ·9795 | ·6942 |
| Dumortierite ...... | ·8897 | ·6871 |

For staurolite the values are taken from Goldschmidt's Winkeltabellen with the *a* and *c* axes interchanged.

There was some question in the writer's mind as to whether the orientation chosen was the best or whether the present prism {210} had not better be made the unit prism. The cleavage is parallel to this prism and the twinning also bears some relation to this form. Moreover, the ratio above given for staurolite, though adopted by Goldschmidt, is not, in the writer's opinion, the best one for that mineral. The one given by Dana, who makes the *a* axis just half as long, would be the better one. The common form of staurolite is prismatic with a prismatic angle of 50° 40′ (Dana).

For andalusite, on the other hand, the prismatic angle is 89° 12′ and the *a* axis should be ·9861 as given. Should dumortierite be classed crystallographically with staurolite or with andalusite? Unfortunately, the evidence is almost too meager to decide this question. On the California crystals the unit prism is poorly developed, and entirely absent from the New York crystals, the strongest form next to the brachypinacoid being the prism {320}. The prismatic cleavage is parallel to {210}, and making the cleavage form the unit prism the *a* axis should be given half its present value. On the other hand, the Arizona crystal is of the typical andalusite habit and making the prism the unit one, we obtain the axes as here given. Giving staurolite the (approximate) axes as andalusite and dumortierite, the prismatic cleavage is parallel to the same form as in dumortierite, namely {210}.

### *Chemical.*

In 1881, after the first announcement of the discovery of the mineral had been made by Gonnard, Damour gave the following analysis of the mineral:

| | |
|---|---|
| $SiO_2$ | 29·85 |
| $Al_2O_3$ | 66·02 |
| $Fe_2O_3$ | 1·01 |
| MgO | ·45 |
| Ign. | 2·25 |
| | 99·58 |

Sp. gr. 3·36

From this analysis the formula $4Al_2O_3.3SiO_2$ was calculated. Damour did not suspect the presence of boric acid in the mineral and what was weighed as alumina probably contained several per cent $B_2O_3$. In 1887 Riggs gave an analysis of the New York mineral in which he found 4 per cent $B_2O_3$. Two years later Whitfield gave several analyses of American dumortierite, all showing the presence of $B_2O_3$. In 1899 Linck gave some observations on the mineral, including an analysis by

W. Schimpff showing a strong test for boric acid. In 1902 Ford gave us three analyses of American dumortierite and also mentioned two new localities. During the winter of 1903–4 the writer made an analysis of the California dumortierite collected by himself during the previous summer. An analysis was also made at the same time of the Washington dumortierite kindly furnished by Mr. Brereton.

Believing that one good analysis is better than several poorer ones for the exact determination of the formula of the mineral, there will be presented an analysis of the California dumortierite made by the writer. From this a formula has been calculated for the mineral, and it will be shown how the other analyses agree with this proposed formula. Before giving the results a few preliminary words will not be out of place.

An analysis of dumortierite is a difficult operation. The small amount of silica makes it difficult to get a good fusion. On preliminary trials on an analysis of the California dumortierite, it was found that what was weighed as silica, in the regular course of the analysis, contained more or less of the undecomposed mineral. Results of about 30 to 32 per cent were obtained. This is, of course, on the uncorrected silica. It was found that a second fusion of the supposed silica was not only very beneficial but also necessary. What was then weighed as silica contained but little residue. The handling of so large an amount of alumina is very cumbersome and an accurate determination of the alumina (plus iron and other oxides here precipitated) is difficult. The boric acid determination is a tedious and difficult one. The accurate determination of the water, which is only given off at a high temperature, is also not easy. One can thus see that an analysis of such a mineral is a difficult operation and that a greater allowance must be made than for most silicate mineral analyses.

The specimen analyzed was selected in the field, an exceedingly pure piece weighing about ten grams being selected. The specific gravity of this piece was taken by suspension in water, giving 3·306. This was broken into small pieces and carefully examined for muscovite, quartz, or other minerals. Sections of the mineral showed that the dumortierite was free from any inclusions. No grains of any titanium mineral abundant in the quartz could be detected. When the mineral was powdered it was treated with heavy solution of sp. gr. 3·10, and a minute amount of mineral (muscovite?) stayed on top and was removed. The separation was repeated several times, the powder dried at 100° and carefully examined under the microscope for impurities. None were found. The mineral was unquestionably pure.

The general analytical methods used were those pursued in the Survey laboratory for silicate analysis with a few modifications. The mineral was fused with sodium carbonate, the silica separated and refused with sodium carbonate. The silica was filtered off and weighed and treated with HF, which left some residue. The alumina (plus iron and titanium) was precipitated three times to be sure of removing all of the sodium salts. It was ignited and weighed with the silica residue, fused with sodium bisulphate, some silica recovered, the iron reduced and determined by titration and the titanium determined colorimetrically. The presence of titanium was suspected from the color of the pleochroism of the mineral. The boric acid was determined by the Gooch method, using all of the known precautions. The mineral was twice fused with sodium carbonate and the boric acid was finally weighed as lime borate. The water was collected in a calcium chloride tube, the mineral being heated in a Gooch tubulated crucible in the usual manner. A blank determination was run before and after each water determination and a small correction applied. All possible precautions were taken throughout the analysis, which was made in duplicate. The results are:

| | 1 | 2 | Average. |
|---|---|---|---|
| $SiO_2$ | 28·58 | 28·78 | 28·68 |
| $Al_2O_3$ | 63·31 | 63·30 | 63·31 |
| $Ti_2O_3$ | 1·49 | 1·40 | 1·45 |
| $Fe_2O_3$ | ·21 | ·25 | ·23 |
| $H_2O$ | 1·53 | 1·51 | 1·52 |
| $B_2O_3$ | 5·21 | 5·53 | 5·37 |
| | 100·33 | 100·77 | 100·56 |

The titanium is regarded as present as $Ti_2O_3$, replacing the alumina.

Combining the alumina, titanium and iron, the following ratios are obtained:

| | | | |
|---|---|---|---|
| $SiO_2$ | 5·94 | or | 6 |
| $Al_2O_3$ | 8·00 | | 8 |
| $B_2O_3$ | 1·06 | | 1 |
| $H_2O$ | ·96 | | 1 |

The formula for dumortierite then is

$$8Al_2O_3 . 1B_2O_3 . 1H_2O . 6SiO_2.$$

It has not been proven that either boric acid and alumina or boric acid and hydroxyl may mutually replace each other in minerals as fluorine and hydroxyl are known to do. There is then no reason that the writer can see why the alumina, boric acid and water in dumortierite should not be present in fixed quantities; that the variations shown in analyses are not due to "isomorphous replacements" but to inaccuracy of analyses or impure material.

Having established the above formula from the analysis, let us see how close the other analyses conform to the formula.

The best series of analyses is that by Ford from three American localities. His first analyses of the Arizona mineral are:

| | 1 | 2 | 3 | Average. |
|---|---|---|---|---|
| $SiO_2$ | 30·00 | 29·66 | 29·91 | 29·86 |
| $Al_2O_3$ | 63·20 | 63·74 | 63·76 | 63·56 |
| $Fe_2O_3$ | ·23 | ·23 | | ·23 |
| $B_2O_3$ | 5·47 | 5·06 | | 5·26 |
| $H_2O$ | 1·45 | 1·38 | | 1·41 |
| | | | | 100·32 |

The ratios calculated from the average analysis gives:

| | | | |
|---|---|---|---|
| $SiO_2$ | 6·29 | or | 6 × 1·05 |
| $Al_2O_3$ | 7·94 | | 8 × ·99 |
| $B_2O_3$ | ·96 | | 1 × ·96 |
| $H_2O$ | 1·00 | | 1 × 1·00 |

The agreement with the proposed formula is perfect.

His second analysis, that of the California mineral, shows slight variations from the results obtained by the writer. The presence of titanium was not determined. His analysis is:

| | | | Ratios. | |
|---|---|---|---|---|
| $SiO_2$ | 30·58 | 6·17 | or | 6 × 1·03 |
| $Al_2O_3$ | 61·83 | 7·40 | | 8 × ·93 |
| $Fe_2O_3$ | ·36 | | | |
| $B_2O_3$ | 5·93 | 1·04 | | 1 × 1·04 |
| $H_2O$ | 2·14 | 1·45 | | 1 × 1·45 |
| | 100·84 | | | |

The ratios agree well with the new formula except for the water content. Remembering, however, that the amount of water present is very small and that a difference of ·10 per cent would make a large difference in the ratios, that Ford determined his water by igniting the mineral with lime, thus not weighing the water directly, and that the writer obtained only 1·52 per cent on the same mineral from the same locality, it seems much more preferable to regard the determination of the water in Ford's analysis as too high rather than to attempt an explanation of it by the assumption of "isomorphous replacment, etc."

Of the third analysis by Ford, of the New York mineral, he says: "It is fully realized that the results are not to be looked upon as being as exact as those of the other analyses." His analysis is:

| | | | Ratios. | |
|---|---|---|---|---|
| $SiO_2$ | 31·24 | 6·23 | or | 6 × 1·04 |
| $Al_2O_3$ | 61·26 | 7·23 | | 8 × ·90 |
| $Fe_2O_3$ | ·10 | | | |
| $B_2O_3$ | 6·14 | 1·06 | | 1 × 1·06 |
| $H_2O$ | 2·09 | 1·40 | | 1 × 1·40 |
| | 100·83 | | | |

Again assuming that his water content is somewhat high, the ratios agree well with the new formula.

This concludes the list of analyses of dumortierite which were made on pure material and with due knowledge of what was to be determined. A number of other analyses will now be given which serve in a general way for the determination of the composition of the mineral, but can not be relied on for exact results.

One, which has heretofore not been published, was made by the writer on the Washington dumortierite. About 200 grams of the rock was powdered and by repeated separation with heavy solutions about 4 grams of dumortierite were obtained. The sample was by no means pure. It was found impossible to remove all the andalusite, an unknown but small amount remaining. It was found during the course of the analysis that the sample also contained some titanite (leucoxene) and a very small amount of pyrite. The analysis was made with all the care possible and the following results were obtained:

| | | Ratios after deducing titanite. | | |
|---|---|---|---|---|
| $SO_2$ | 28·51 | 5·97 | or | 6 × ·99 |
| $Al_2O_3$ | 59·75 | | | |
| $Fe_2O_3$ | 2·48 | 7·80 | | 8 × ·97 |
| $TiO_2$ | ·95 | | | |
| $H_2O$ | 2·12 | 1·53 | | 1 × 1·53 |
| $B_2O_3$ | 5·54 | 1·03 | | 1 × 1·03 |
| CaO | ·68 | | | |
| | 100·03 | | | |

Excepting for the high-water content, the analysis agrees very well with the formula. No allowance was made for the small amount of andalusite present, which would slightly alter the ratios.

There now remain the analyses of Whitfield and Riggs, of which but one is suitable for any calculation. The analyses are as follows, No. 1 being of the New York mineral, by Riggs, No. 2 of the New York, and Nos. 3 and 4 of the Arizona mineral, by Whitfield:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $SiO_2$ | 34·82 | 31·44 | 31·52 | 27·99 |
| $Al_2O_3$ | 55·30 | 68·91 | 63·66 | 64·49 |
| MgO | ·57 | .... | ·52 | tr. |
| $K_2O$ | 1·04 | .... | ·11 | .... |
| $Na_2O$ | 1·76 | .... | ·37 | .... |
| $P_2O_5$ | .... | .... | .... | ·20 |
| $B_2O_3$ | 4·07 | tr. | 2·62 | 4·95 |
| Ign | 2·96 | .... | 1·34 | 1·72 |
| | 100·52 | 100·35 | 100·14 | 99·35 |

The ratios of the last analysis are:

| | | | |
|---|---|---|---|
| $SiO_2$ | 5·94 | or | $6 \times$ ·99 |
| $Al_2O_3$ | 8·09 | | $8 \times$ 1·01 |
| $B_2O_3$ | ·80 | | $1 \times$ ·80 |
| $H_2O$ | 1·22 | | $1 \times$ 1·22 |

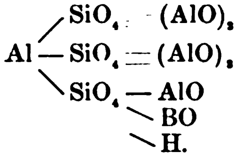
Approximately they agree with the formula.

The only question of which there seems to be any doubt is whether the water should be 1 or 1½ molecule. As, however, the best analyses show but 1 molecule and their evidence is considered as of much more value than a large number of inferior analyses, there is no question in the writer's mind but that the formula for dumortierite is

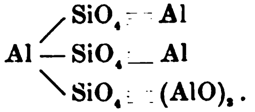
$$8Al_2O_3.1B_2O_3.1H_2O.6SiO_2.$$

This may be written $(SiO_4)_3Al(AlO)_7(BO)H$, which is the same as the formula given by Groth except that for (BO) he puts (AlO). His formula is $(SiO_4)_3Al(AlO)_8H$.

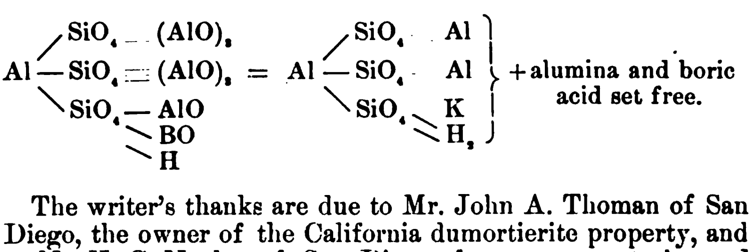
This may be written in the following form:



This formula is similar to that of andalusite, which is written



Dumortierite alters to muscovite. The change can be very well shown by these formulæ and seems to be entirely in accordance with the group of minerals to which it is related.


**Dumortierite.** **Muscovite.**

The writer's thanks are due to Mr. John A. Thoman of San Diego, the owner of the California dumortierite property, and to Mr. K. C. Naylor of San Diego, for many courtesies and favors.

## ART. XVII.—*Crystallography of Lepidolite;* by WALDEMAR T. SCHALLER.

A GROUP of lepidolite crystals was collected by the writer in the summer of 1904, at a gem mine about four miles east of Ramona, on the stage road from Ramona to Julian, San Diego County, California. The mine was opened and worked for its gems, such as topaz, tourmaline, garnet, etc. With these are associated quartz, orthoclase in good crystals at times several feet long, and muscovite, and, rarely, lepidolite. The minerals in question all occur in the loose dirt, filling "pockets" in a pegmatite dike.

The specimen of lepidolite under consideration consists of a group of intergrown crystals which often reach a large size. The group itself is about $5^{cm}$ thick and the individual crystals measure about $1^{cm}$ across the base, though ones with a diameter of $2^{cm}$ are not rare. The crystals are also proportionally thick, the average being from 2 to $4^{mm}$, though a few are somewhat thicker. They are transparent and of a very pale pink color, and, in the direction normal to the vertical axis and parallel to the base, of a slightly deeper tint. They fuse easily to a white enamel, coloring the flame an intense crimson. The side faces are usually plain, not rounded nor striated, and of a brilliant polish, giving excellent signals. It is, however, extremely difficult to secure a complete crystal from the group, owing to the perfect basal cleavage which will cause a crystal to split into a number of layers. This will also at times cause part of a crystal to become slightly displaced. In consequence of this difficulty, most of the crystals measured are only parts of the original crystals, and two such pieces measured as separate crystals may, in reality, be parts of one and the same crystal.

As may be expected, the crystals of lepidolite are similar to those of muscovite. The interfacial angles are nearly the same and the crystals are naturally referred to the same axes as muscovite. There are three marked differences between these crystals and those of muscovite: (1) the rarity of twins—only one being found in twenty-one crystals; (2) the absence of the characteristic face of muscovite, M = $\{221\}$; and (3) the presence of the *a* face $\{100\}$, occurring on ten out of twenty-one crystals. The crystals are not so striated as the green North Carolina muscovites for instance, and in many cases the faces yielded perfect signals.

The common forms are $c = \{001\}$, $b = \{010\}$, $a = \{100\}$, $e = \{023\}$, $o = \{112\}$, $u = \{\bar{1}11\}$, and $x = \{\bar{1}31\}$. Besides these, the following have been determined; $N = \{261\}$, $z = \{\bar{1}32\}$, 1

$= \{130\}$, and possibly several others, as $\{\bar{2}23\}$, $\{\bar{2}21\}$, $\{\bar{1}12\}$. Also a number of forms occurring for the most part as broad faces, giving good reflections but having anomalous indices and which need further study. The most frequent combination is *choux*, after which comes *chouxea*. Whenever the angle (001): (010) could be accurately measured, it was found to be exactly 90° 00′ in every case, and the distribution of the faces also indicate monoclinic symmetry.

It was noticed that the angle between the same forms varied slightly on different crystals. The faces were smooth and highly polished and the angles could easily be measured with an error nor greater than 1′. It is suggested that this variation is real and is due to the fact that lepidolite is an isomorphous mixture of two end products, and as the ratio of these two products varies, the crystallographic and physical properties of the mineral also vary. Further study on the possible correlation of the various properties of the mineral is under way.

This lepidolite belongs to the "second class" of Tschermak or the "brachydiagonal class" of Scharizer, i.e., the axial plane is parallel to the clinopinacoid, and not normal to it. The trace of the axial plane was always parallel to one arm of the percussion figure. The above is only a brief preliminary statement; the detailed crystallography of the mineral will soon be published in a paper on the mineralogy of this entire field of lithium minerals in southern California. The writer's thanks are due Mr. Pan McIntosh, Jr., of Ramona, the owner of the mine.

Chemical Laboratory, U. S. Geological Survey.

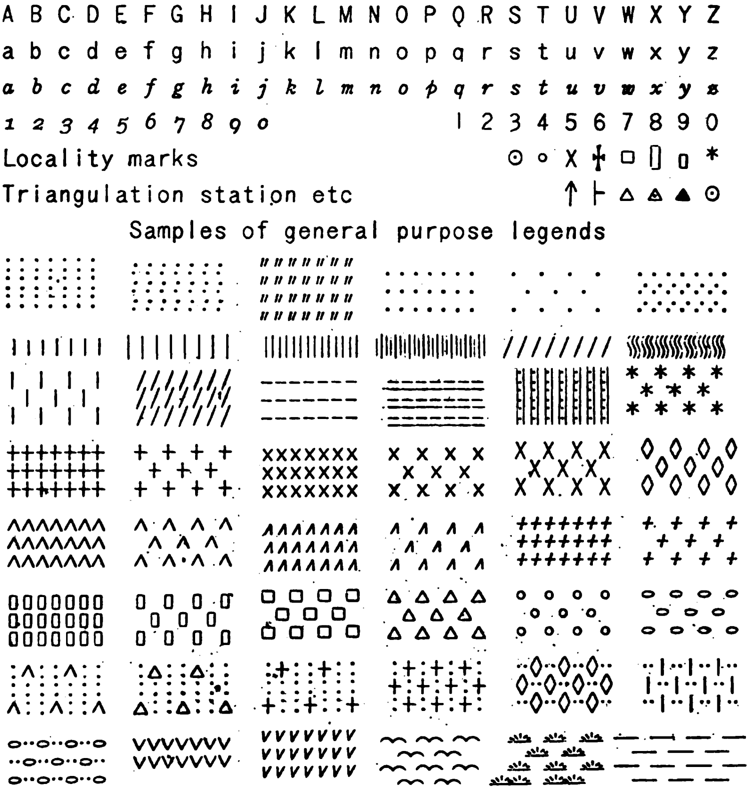
# Art. XVIII.—*Machine-Made Line Drawings for the Illustration of Scientific Papers;* by R. A. Daly.

It is safe to say that the majority of persons, who from time to time publish scientific papers, are seriously hampered in the preparation of text illustrations by the difficulty and expense entailed in the tedious drawing of map, section or diagram. Comparatively few authors can command the services of skilled draughtsmen or have themselves the requisite training to produce satisfactory line drawings. Yet the desirability of greatly increasing the proportion of such illustrations in the thousands of scientific articles published each year is manifest. That clearness, precision and conciseness in the exposition of a theme are generally enhanced by the use of abundant, appropriate diagrams is as evident as that the blackboard is the constant friend of the teacher of any branch of natural history or philosophy; the printed page needs its blackboard.

Ideally, the author should himself be able to make the original drawing quickly, neatly and artistically. The usual execution of drawing with the pen is, to the average author, discouragingly slow and expensive, not always neat, and still less often artistic. The following note relates to some experiments made to increase rapidity and neatness in the production of line drawings by the use of a machine. At the outset the experiments were, for obvious reasons, planned without any idea of rivalling the artistic work of the pen in a skilled hand. The aim has been to secure economy of time in execution and clear-cut precision of legend for the drawing. In both these respects enough success has been attained to warrant the recommendation of the machine method to geologists, geographers and others who desire to prepare useful text illustrations at a minimum cost of labor. Some experimental drawings were made and published in the Bulletins of the Museum of Comparative Zoology at Harvard College, vol. xxxviii, 1902, pls. 11, 12 and 13; in this Journal, August 1903, pp. 118 and 120; and in the American Geologist, August 1903, p. 66. The machine there used was an ordinary Underwood typewriter fitted with a black record silk ribbon.

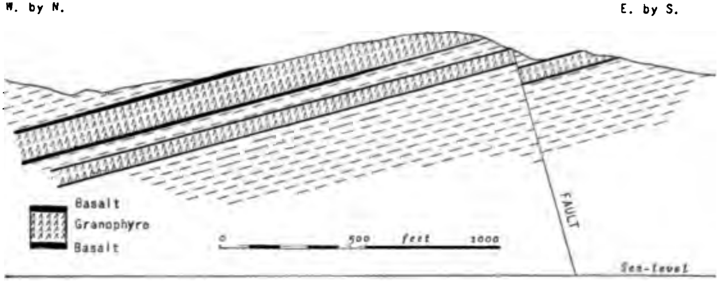
Recently the Hammond Typewriter Company of New York has constructed, for the Geological Survey Department of Canada, from the writer's specifications, a typewriter provided with a carbon ribbon and with ninety special characters designed for the preparation of line drawings to accompany geological and geographical papers. The same machine can be similarly used for statistical, engineering and other diagrams of a more or less mechanical and simple composition. Of course this method should not wholly replace the use of the pen, even, for example, in the differentiation of areas in a geological map or section. The ultra mechanical look of the typewritten legend can often be pleasingly relieved by the easily and quickly applied cross-hatchings, etc., made with an ordinary drawing pen. In complex diagrams free-hand work may generally be expected to supplement the work of the machine. The subject of each diagram should thus be studied with the end of securing suitable contrasts of legend along with the maximum economy of pen work; yet some pen work is almost always necessary.

1


A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
a b c d e f g h i j k l m n o p q r s t u v w x y z
a b c d e f g h i j k l m n o p q r s t u v w x y z
1 2 3 4 5 6 7 8 9 0
1 2 3 4 5 6 7 8 9 0
Locality marks
Triangulation station etc
Samples of general purpose legends

The typewriter has its most general application in lettering, that most difficult element in line drawings. The machine used by the writer has the advantage of making it possible to employ a great range of type styles. With the carbon ribbon the writer has found that any one of the one hundred and twenty-five shuttles made for such a machine (each shuttle bearing ninety characters and including the lettering for one of twenty-six different languages), will give an impression suitable for photographic reproduction. Each shuttle can be placed in the machine ready for work in a few seconds. The usual silk ribbon gives a "woolly" line, and is far less satisfactory than the carbon ribbon. A highly calendered and high-grade linen paper of a medium to heavy weight or a thin Bristol board may be recommended. Often more than one impression of the key is necessary to obtain the required depth of tint for photography; such repeated impressions can be made at great speed by employing a back spacing key. Care must be taken not to smudge the carbon of the completed printing.

2



The accompanying cuts serve to show something of the method as applied to geological diagrams. The diagram (fig. 1) of alphabets and legends has been reduced to four-fifths of its original diameter. The legends are intended to represent a few examples of those possible with the machine. They can be indefinitely increased in number and varied in design by the engraving of new characters on the shuttle, and by using various permutations and combinations of the existing characters. The section (fig. 2) is reduced to about one-half of its original diameter. It was copied from Harker's section of a composite triple sill published in "The Tertiary Igneous Rocks of Skye" (Memoir of the Geological Survey of the United Kingdom, 1904, p. 204). The result represents the saving of from seventy-five to ninety per cent of the time required by a draughtsman to duplicate the drawing.

It is to be understood, of course, in the preparation of a diagram that an outline drawing is first prepared, and that the spaces thus formed are filled with the symbols shown in the legends, by means of the machine.

**Ottawa, Canada.**

## ART. XIX.—*Iodobromite in Arizona;* by WILLIAM P. BLAKE.

THE rare compound of silver, iodine, bromine and chlorine, iodobromite, occurs in thin seams and crusts in a vein of quartz and calcite near Globe, Pinal County, Arizona. The crystallization is obscure. It is soft like talc; luster vitreous; color light lemon-yellow to sulphur- and canary-yellow. Not being able to secure enough for a satisfactory quantitative analysis, the results of the determinative tests are added. The reactions before the blowpipe are remarkably beautiful and interesting. Heated in a closed tube with bisulphate of potash, the mineral quickly changes color to a dark salmon, or orange-red, heavy brownish-red fumes of bromine are given off and bromine condenses in the higher portion of the tube; violet vapor of iodine then appears and crystals of iodine form below the condensed bromine. The fused assay, floating in the flux, is brilliant cherry red, at first very dark red, but on cooling gradually loses this color, passing through various shades of red until the normal yellow color is restored. The fused mass then being removed from the tube and reheated until the bromine and iodine are expelled, and treated with carbonate of soda on charcoal, a button of metallic silver is obtained. The fused carbonate of soda dissolved from the coal gives the reaction for chlorine with silver nitrate. In the final reduction of the assay to the metal a slight yellow areola like that from lead was observed and referred to probable slight impurity.

Arizona School of Mines, Tucson, Arizona.

# ART. XX.—*Autophytography: A Process of Plant Fossilization*; by CHARLES HENRY WHITE.

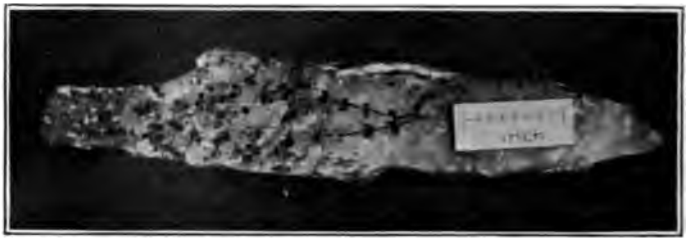
THE evidence for the existence of plant life on the earth in past geological ages is both direct and indirect. We may include in the class of direct evidence all the records of vegetable life in which the form or structure of the plant is in any degree preserved, and in the class of indirect evidence, such as offer no clew to plant form, but merely indicate in a secondary way, the existence of vegetable life. In this latter class are coal and certain deposits of calcareous and siliceous sinters and bog-iron-ore. The plant records to which attention is especially directed in this paper may be placed in the category of direct evidence, since the trace or outline of the plant is distinctly preserved; but the process by which the outline is recorded in the rocks is wholly different from those processes to which the formation of plant records is usually attributed.

The ways usually described by which the plant form is recorded in the rocks may be included in the following three classes. The first class includes those in which the original substance, or tissue, of the plant is, in part at least, preserved. Such remains are often found within, or in close association with, deposits of shale, peat, coal, diatomaceous earth, and the like. The second class of records by which the form is preserved is that in which the plant tissues have been removed by decay or otherwise, leaving only the impress or mould as the record in the rocks. The third class is that in which the mould has been filled by a cast, either after the complete removal of the plant, or by a gradual so-called molecular replacement.

By the process of plant fossilization here described, the plant undergoing decomposition reproduces itself in outline on the rock surface upon which it rests, or upon the matrix within which it is enclosed, either by the precipitation of colored mineral matter, or by the alteration or removal of the coloring matter already in the rock. In the first of these processes the rock surface receives a deposit of colored mineral matter, a positive picture,—to borrow the language of the photographer,—is made (see figures 1 and 2); and in the second, the uniform coloring matter already in the rock is abstracted where the plant, during growth or decay, has been in contact with it, giving a plant picture in lighter color, a negative (figures 3 and 4). For such plant pictures, or plant writings, in which the traces or outlines of plants are distinguishable by their color, and in which the variation of color from the matrix is due to chemical change brought about by the plant reproduced, the name autophytograph (αὐτός = self, φυτόν = plant, γραφω = write) is proposed.

Figures 1 and 2 represent specimens of the positive autophytograph that were collected by Dr. John W. White in December, 1897, from a bar of gravel on Cub Creek in the town of Wilkesboro, North Carolina, and were presented to the writer in January, 1898. These specimens* are water-worn pebbles of white quartzite that have been slightly stained brownish yellow by hydrated iron oxide, and that have, in recent time,

1



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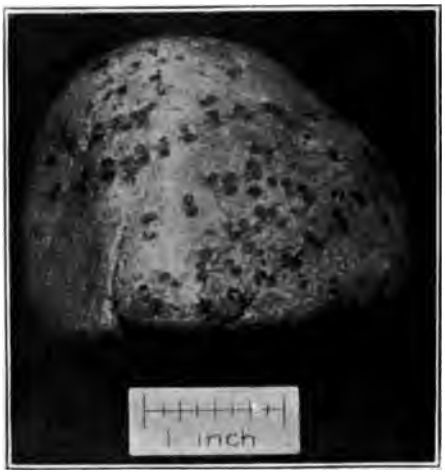

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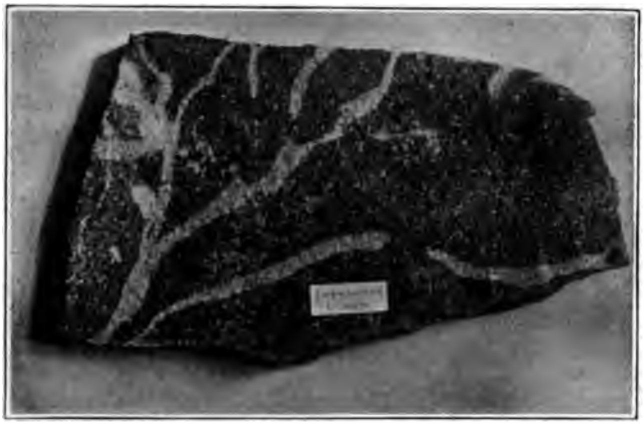
* All the specimens reproduced here are in the Harvard University Museum. Figures 1 and 2 are from two specimens No. 2559, figures 3 and 4 are Nos. 2667 and 2343, of the Geological Laboratory collection; and figure 5 is from No. 37 of the Students Palaeontological collection.

received a black deposit on their polished and stained surfaces, reproducing so perfectly the stem and leaves of a small herb that the species is readily identified. These autophytographs were determined by Mr. M. L. Fernald at the Gray Herbarium, Harvard University, through the kind intervention of Mr. Walter Deane, of Cambridge, Massachusetts, as having been produced by *Micranthemum orbiculatum* Michx., a small creeper that flourishes in low, muddy ground, from Florida to North Carolina.

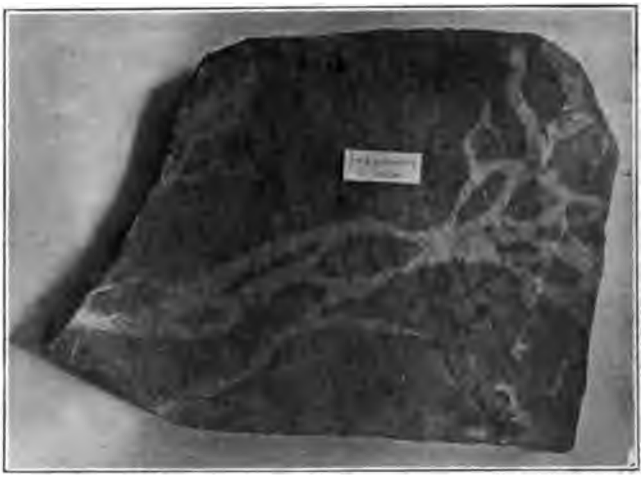
The composition of the pigment of these autophytographs is difficult to determine, owing to the small quantity of material available. It is, however, a black adherent deposit, insoluble in water, but slowly attacked by the mineral acids, yielding solutions which show the presence of iron. No change of color is produced by the flame of the blow-pipe, but the pigment becomes strongly magnetic on heating. There is no doubt, therefore, that the colored deposit contains iron, and it is most probably an oxide. Two possible conditions under which it is believed such a deposit could form are suggested. First, the plants of this genus may yield on decomposition a precipitant of iron, peculiar to the genus, which extracts iron from the surrounding solutions and deposits it in a manner analogous to one of the artificial ink-making processes, and on exposure to the air the precipitate is changed to an oxide. The other suggestion is, that the conditions of decay are such that ammonia is liberated in the presence of iron in solution, precipitating the iron on the rock upon which the plant rests

3



during decay. For the precipitate to remain permanent, ammonia must be produced gradually and in sufficient quantity to neutralize the acid in the iron-bearing solution until the acid ceases to flow to the point of deposition. That vegetable matter undergoing decay will under certain and usual conditions produce acids which take iron in solution, and will under other conditions yield ammonia, is well known and need not be discussed here; but the nicety of adjustment of these conditions called for above would necessarily be rare, and,—if this be the correct theory,—would account for the scarcity of autophytographs of this description.

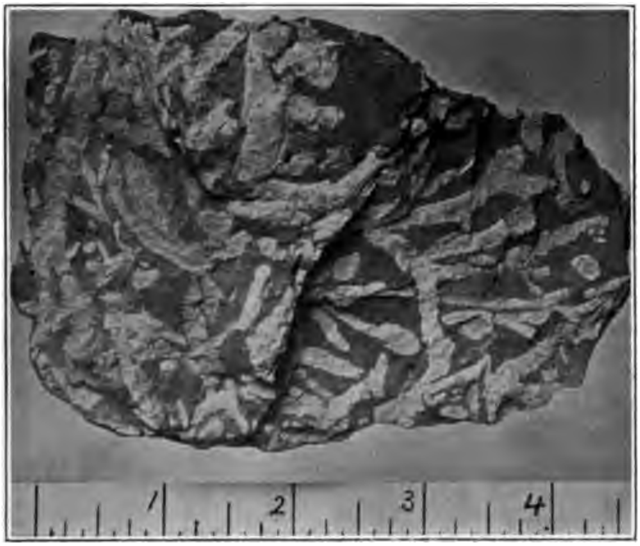
4



In figures 3, 4 and 5 are reproduced autophytographs of the negative type. The specimens represented by figures 3 and 4 are autophytographs of recent formation that were collected by Professor J. B. Woodworth of Harvard University, and it is through his kindness that they are here reproduced. The specimen represented by figure 3 is a block of sandstone, taken from the Saratogan, or upper Cambrian, formation near Biddle's Crossing, about a mile and three-quarters north of Sciota, Moore's quadrangle, Clinton County, New York, on which rootlets have in recent time brought about solution of the iron-pigment which stained the sandstone a yellow-brown, giving an autophytograph of lighter color on a dark background. Figure 4 represents a specimen taken from the ploughed surface of a lateral moraine at the west base of Bald Hill near Caroline Depot, Tompkins County, New York. This specimen differs from the last only in having a darker iron-pigment in the rock, and in the form of the root reproduced, but in neither case is the portion of the plant reproduced sufficiently characteristic to identify the species.

These autophytographs belong in no sense to a past geological age. They were formed on or near the present land surface and show little evidence of having suffered disintegration and erosion. Granting that in transportation and deposition the probabilities are decidedly in favor of the destruction of these plant records, yet there are conditions of deposition and burial, not at all rare in nature, that would very effectively preserve such records to future geological time. While the specimens so far considered belong to the present and have no value as records for the historical geologist or palaeontologist, they well illustrate the process of autophytography and, as just pointed out, lead us to expect fossils of this character in the plant-bearing horizons of past geological time.

5



At the suggestion of Professor R. T. Jackson, the collection of fossil plants in the Harvard Botanical Museum was inspected, and it was found that fossil plants from many horizons partake of the quality of the autophytograph of both the positive and the negative type. Plant impressions in the slates at Solenhofen, Bavaria, marked out by oxide of iron have been observed by Seward,[*] and similar impressions in the Buntersandstein of the Vosges were found by Schimper and Mougeot[†] to have either received a deposit of hydrated ferric oxide or to have had the red color of the rock removed from about the plant impression, the intensification or the removal of the coloring depending on the locality and the nature of the rock. In the Harvard collection are representatives of both these types from the Vosges and also from the Solenhofen deposits, as well as from many other localities. There are also examples in which the plant has left no impression or mould on the rock, but, at the same time, has been perfectly fossilized by negative autophytography. A fair representative of this class from the Lias of Germany is shown in figure 5. It is a specimen of *Fucoides bollensis*, collected at Boll, Würtemberg.

The various classes of evidence for the existence of plant life may be summarized as follows:

- Evidences of plant life
  - Direct
    - Vegetable substance
      - Original tissue
      - Carbonized
    - Mould or impression
    - Cast ...............
      - External form only
      - Internal structure
    - Autophytograph ...
      - Positive
      - Negative
  - Indirect .. Graphite, coal, sinter, bog-iron-ore

Harvard University, Cambridge, Mass.

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[*] A. C. Seward, Fossil Plants, vol. i, p. 68.

[†] Schimper et Mougeot, Monographie des plantes fossiles du grès bigarré de la Chaîne des Vosges, p. 10.

## ART. XXI.—*The Oxidation of Sulphites by Iodine in Alkaline Solution;* by R. HARMAN ASHLEY.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxiv.]

ACCORDING to Bunsen, Dupasquer's method of oxidizing sulphurous acid by iodine in an acid solution, proceeds to completion according to the equation

$$2SO_2+2I_2+4H_2O=4HI+2H_2SO_4$$

only when the concentration of the sulphur dioxide does not exceed 0·5 per cent of the solution. When, on the other hand, the proportion of sulphur dioxide exceeds this value, there is a secondary reaction, which according to Volhard, involves the reduction of the sulphur dioxide by the hydriodic acid produced. This difficulty may be obviated, however, as has been shown by Volhard,* if the solution of the sulphurous acid or a sulphite is run with stirring into a solution of iodine in potassium iodide, acidified with hydrochloric acid, to the bleaching of color, using starch as an indicator,—a procedure which is obviously less convenient than direct titration by a standard solution of iodine.

It has been recently further proposed by E. Rupp† to accomplish the oxidation in an alkaline solution, by treating the solution of sulphur dioxide or a sulphite, with an excess of standard iodine in presence of acid sodium carbonate, 1 gr., during an interval of fifteen minutes, and determining the excess of iodine with sodium thiosulphate. Rupp's analytical examples, three in number, involving amounts of sulphur dioxide approximating 0·0343 gr., show small errors of excess, and from them the conclusion is drawn that sulphites like arsenites, may be estimated in a solution made alkaline with sodium bicarbonate, by the process indicated.

This very unusual use of sodium thiosulphate for the determination of free iodine in the presence of an alkali bicarbonate, suggests the question as to whether the sulphite was in reality completely oxidized by the treatment, or whether the apparently good results were in fact due to a chance balancing of errors of incomplete oxidization of the sulphite, on the one hand, and on the other hand, of the excessive use of iodine in the action of the thiosulphate in an alkaline solution, it being generally supposed that in alkaline solutions not only is the expected tetrathionate formed, but that some of the thiosulphate is oxidized to the extent of forming sulphate rather than tetrathionate exclusively.

In the following table of experiments are data of experiments upon the action of iodine and sodium thiosulphate in alkaline solution. The sodium thiosulphate, approximately $\frac{N}{10}$, was standardized against approximately $\frac{N}{10}$ iodine solution in a neutral solution. Varying amounts of a saturated solution of acid sodium carbonate were used to render the solution alkaline in the experiments recorded.

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*Ann. Chem., ccxlii, 93. † Ber. Dtch. Chem. Ges., xxxv, 3694.

TABLE I.

Iodine solution = 0·01236 gr. per cm³.
Sodium thiosulphate solution = 0·01516 gr. per cm³.

| No. | $Na_2S_2O_3$ nearly $\frac{N}{10}$ | | Iodine nearly $\frac{N}{10}$ | | Error in terms of I. | $NaHCO_3$ | Treatment. |
|---|---|---|---|---|---|---|---|
| | cm³ | I value, gr. | cm³ | gr. | gr. | cm³ | |
| 1. | 11·94 | 0·1451 | 15·00 | 0·1854 | +0·0403 | 20 | $Na_2S_2O_3$ into Iodine. |
| 2. | 11·69 | 0·1421 | 15·00 | " | +0·0433 | 20 | |
| 3. | 11·18 | 0·1359 | 15·00 | " | +0·0495 | 40 | |
| 4. | 11·25 | 0·1367 | 15·00 | " | +0·0487 | 40 | |
| 5. | 9·18 | 0·1116 | 11·00 | 0·1360 | +0·0244 | 1 gr. | |
| 6. | 9·11 | 0·1107 | 11·00 | " | +0·0253 | 1 gr. | |
| 7. | 15·00 | 0·1823 | 15·98 | 0·1975 | +0·0152 | 20 | Iodine into $Na_2S_2O_3$ |
| 8. | 15·00 | " | 16·31 | 0·2016 | +0·0193 | 20 | |
| 9. | 15·00 | " | 16·62 | 0·2054 | +0·0231 | 40 | |
| 10. | 15·00 | " | 16·65 | 0·2058 | +0·0235 | 40 | |

It is plainly evident from the table that more iodine is used up in the presence of an alkali bicarbonate, whether the iodine is run into the thiosulphate or the thiosulphate into the iodine, than accords with the theory of the reaction.

Experiments were now undertaken for the purpose of contrasting the results obtained by Rupp's procedure with results found by oxidizing the sulphite with iodine in an alkaline solution and determining the excess of iodine by standard arsenite, which, as is well known, acts with regularity upon iodine in the presence of an acid sodium carbonate. The volumes of the solutions at the time of oxidation varied from 25cm³ to 50cm³. The results are given in the following table:

TABLE II.

RUPP'S PROCEDURE.

| Iodine value of $SO_2$ taken. | Iodine taken. | Iodine value of $Na_2S_2O_3$ taken. | $NaHCO_3$ taken. | Error in terms of Iodine. | Error in terms of $SO_2$ |
|---|---|---|---|---|---|
| gr. | gr. | gr. | gr. | gr. | gr. |
| 0·0977 | 0·2474 | 0·1492 | 1· | +0·0005 | +0·0001 |
| 0·0977 | 0·2474 | 0·1454 | 1· | +0·0043 | +0·0011 |
| 0·1440 | 0·2969 | 0·1528 | 1· | +0·0001 | +0·0000 |
| 0·1440 | 0·2969 | 0·1518 | 1· | +0·0011 | +0·0003 |
| 0·2759 | 0·4316 | 0·1582 | 1· | −0·0025 | −0·0006 |
| 0·2759 | 0·4316 | 0·1628 | 1· | −0·0071 | −0·0018 |

EXCESS OF IODINE DETERMINED BY STANDARD ARSENITE.

| Iodine value of $SO_2$ taken. | Iodine taken. | Iodine value of arsenite taken. | $NaHCO_3$ taken. | Error in terms of Iodine. | Error in terms of $SO_2$. |
|---|---|---|---|---|---|
| gr. | gr. | gr. | gr. | gr. | gr. |
| 0·0977 | 0·2495 | 0·1543 | 1· | −0·0025 | −0·0006 |
| 0·0977 | 0·2495 | 0·1540 | 1· | −0·0022 | −0·0006 |
| 0·1440 | 0·2984 | 0·1586 | 1· | −0·0042 | −0·0010 |
| 0·1440 | 0·3017 | 0·1607 | 1· | −0·0030 | −0·0008 |
| 0·2759 | 0·4354 | 0·1710 | 1· | −0·0115 | −0·0029 |
| 0·2759 | 0·4354 | 0·1742 | 1· | −0·0147 | −0·0037 |

From a comparison of the results in the second section of the table with those in the first section, it appears that under the conditions advocated by Rupp, the sulphite is not completely oxidized by the iodine. It seems that enough of the secondary action, by which the thiosulphate is oxidized beyond the condition of tetrathionate, takes place to counterbalance the error of incomplete oxidation when moderate amounts of sulphurous acid are handled, and more than enough for the smallest amounts, the secondary error predominating in such cases.

The results of experiments in which acid potassium carbonate was substituted for the acid sodium carbonate gave similar results.

So it appears that when Rupp's process gives results approximating the truth, it is due to the happy balancing of opposed errors. It seems quite possible that the same balancing of errors likewise occurs in the process for the determination of phosphorous acid described by Rupp and Fink.*

In conclusion, I would like to thank Prof. F. A. Gooch for many kind suggestions.

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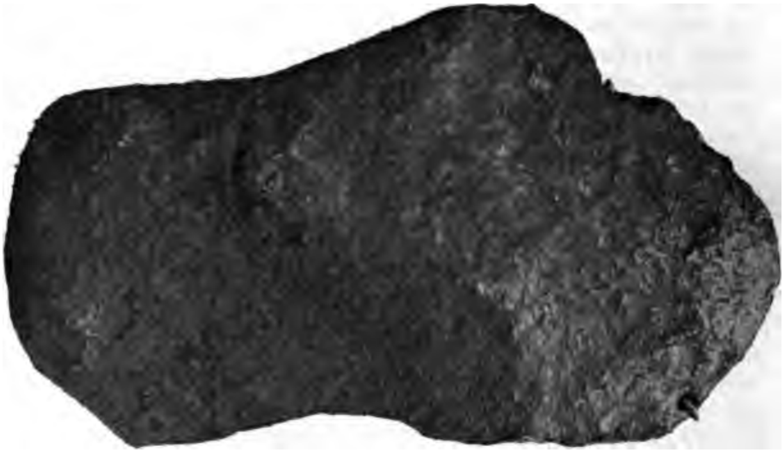
* Ber. Dtch. Chem. Ges., xxxv., 3691, 1902.

# ART. XXII.—*The Billings Meteorite: A new Iron Meteorite from Southern Missouri*; by HENRY A. WARD.

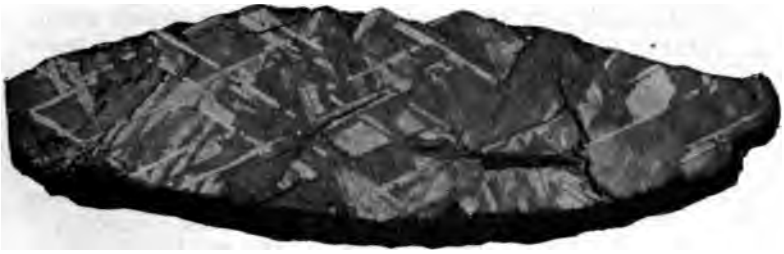
A NEW siderite is now added to the six meteorites (four siderites and two aerolites) already found in the state of Missouri. The mass was found on the farm of Geo. Wolf about four miles east of Billings, Christian County, Southwestern Missouri, in breaking new ground in September, 1903. It was taken by Mr. Wolf—who considered it an iron ore,—to a street fair held in Billings in the same month, where it took the first prize as Iron Ore. The attention of J. P. Thomas was called to it, and he had a horse-shoe nail made from a piece of it and a hole drilled through the edge of the mass to test its quality. Mr. Thomas shipped it with a large number of specimens of iron ore to Kansas City, Mo., where it was bought by Mr. R. E. Bruner, a gentleman who possesses a fine collection of minerals. It remained in Mr. Bruner's hands until I obtained it from him last November.



Billings Siderite, ¼ size.

In general shape the Billings siderite rudely resembles an axe or hatchet, as may be seen from the cut here given. Its extreme length is 15¼ inches; its greatest breadth 8¾ inches. The thickness at the larger end is 5 inches, while from the middle the mass flattens out into a blade or wedge, which is about 3 inches thick on a medium line, and slopes off to a blunt rounded edge at the sides and end. This iron has evidently lain in the ground for a long time since its fall. Its outer surface is rusty and covered with flaking scales of oxide. There consequently remains upon its surface no sure trace of "pitting" or other aerial action incident upon its flight and fall through our atmosphere. A single circular concave depression, four inches across by one inch in greatest depth, on one side of the mass may be the remains of an original pitting on the original surface. The weight of the mass before cutting was 54 lbs. Several slices have been made under my direction which show fine Widmannstätten figures of the octahedral system. Of the structure and composition of the iron alloys inducing these figures I am indebted to Prof. Oliver C. Farrington of the Field Columbian Museum of Chicago for the remarks which follow.

The Billings iron is a coarse octahedrite (Og), with lamellæ averaging from 1–2$^{mm}$ in width. In length many of the lamellæ extend 2$^{cm}$ without interruption. They are as a rule comparatively straight in outline, but again become irregular and swollen and at times merge into areas where their outlines are so nearly rounded as to give a coarse-granular appearance. The substance of the lamellæ is sometimes interrupted and sometimes shows subdivision longitudinally into narrower bands by more or less continuous films of tænite. The kamacite is coarsely granular in character, and shows oriented sheen. The tænite appears as a dark, narrow line, in general bordering the kamacite, but also not infrequently crossing and anastomosing. In portions of the meteorite, where some decomposition has taken place, the tænite separates out as thin, flexible, magnetic plates of a tin-white color.



Section of Billings Siderite, ½ size.

The meshes (Felder) of the section occupy but small space relatively to the bands (Balken) but are well defined where they occur. They range in size from about 25$^{sq\ mm}$ down, and in outline from triangular to trapezoidal. They are filled with a substance darker in color than the kamacite, and are traversed by irregular numbers of delicate plates seen only under a lens, which run now in one and now in several directions. As a rule these plates start in great numbers from the borders of the mesh and thin out toward the center, but in some of the meshes they extend uniformly across. Several nodules of troilite appear in the section examined and as usual occur near its boundary. One of these nodules is irregularly oval in shape and has a diameter of about one centimeter. The others are smaller, and range in outline from nearly circular to considerably elongated. None of them has a border of swathing kamacite. A line of irregular parting extends across the section, following roughly the lamellar planes, except at about the middle of the section, where it runs nearly straight for a distance of about $2^{cm}$ quite irrespective of the lamellar structure. The parting at this point has a width of about one millimeter, and is filled with a substance of the section. This substance shows a foliated structure parallel with the length of the tænite, others kamacite. The structure is evidently secondary in character and appears to be a filling subsequent to the individualization of the main mass.

The chemical analysis of the iron has been made by Mr. H. W. Nichols, the chemist of the Field Columbian Museum, and is as given below:

*Analysis of Billings Iron*

| | |
|---|---|
| Fe | 91·99 |
| Ni | 7·38 |
| Co | 0·42 |
| Cu | 0·01 |
| Si | 0·08 |
| P | 0·15 |
| S | 0·06 |
| | 100·09 |

The larger part of this Billings siderite has taken its place in the Ward-Coonley Collection of Meteorites.

Chicago, Illinois.

# SCIENTIFIC INTELLIGENCE.

## I. Chemistry and Physics.

1. *The Atomic Weight of Iodine.*—A series of careful determinations of this constant has been carried out by G. P. **Baxter** of Harvard University. The ratios of silver to silver iodide, silver to iodine, and silver iodide to silver chloride were found in making these determinations, and the average of very closely agreeing results by the three methods were 126·973, 126·977 and 126·975, where oxygen as 16 is taken as the basis. Several other investigators—Scott, Ladenburg, and Köthner and Aeuer—have recently obtained results upon the same atomic weight which agree almost exactly with those of Baxter; hence it appears certain that the atomic weight 126·85 for iodine, which has been accepted for many years on the authority of Stas and of Marignac, is somewhat lower than the truth. In spite of his wonderful skill, it seems that Stas was not quite infallible in his atomic weight determinations. The international committee on atomic weights, in the table for 1905, has adopted the value 126·97 for the atomic weight of iodine, when oxygen is 16, and the value 126·01, when hydrogen is taken as unity. Both of these numbers, it may be noticed, are curiously close to being confirmations of Prout's old hypothesis, which requires, practically, that the atomic weights should be whole numbers.—*Zeitschr. anorgan Chem.*, xliii, 14. H. L. W.

2. *Double Silicides of Aluminium.* — **Manchot** and **Kieser** have obtained the crystalline compounds $Cr_2AlSi_3$ and $Cr_3AlSi_4$ by the fusion of chromium compounds with an excess of aluminium in the presence of potassium silicofluoride, and treatment of the resulting metallic mass with an acid in order to dissolve the aluminium. The compound, $Cr_2AlSi_3$, forms beautiful slender crystals of hexagonal habit, which are opaque, with a strong metallic luster and white color. The compound is very inactive with most chemical agents. It is insoluble in acids, except hydrofluoric acid; it remains bright when heated in a stream of oxygen, and is not attacked by fusion with potassium bisulphate; but it readily decomposes by fusing with alkalies. The other compound was obtained in a similar way in the presence of a larger amount of silicon. It forms smaller crystals, is somewhat harder, but otherwise it is like the first compound in its properties. These compounds are the first double silicides to be described.—*Ann. der Chem.*, cccxxxvii, 353. H. L. W.

3. *Europeum.*—This element, occurring in very small quantities among the rare earths and coming between samarium and gadolinium, was described by Demarçay several years ago. **Urbain** and **Lacombe** have recently confirmed the existence of the earth. They used 610 g. of oxides representing the whole of the europeum group of earths from about 500 kilos of monazite

sand, and by a long series of fractionations involving some 3000 crystallizations, they obtained several fractions of constant properties and atomic weight, apparently consisting of pure europeum. The amounts obtained indicated that the monazite sand contained about two hundred-thousandths of europeum oxide. The sulphate has a scarcely visible rose tint, while the oxide prepared at a low temperature is practically white, although when intensely ignited it is distinctly rose-colored. Closely agreeing atomic weight determinations made with several different fractions gave 151·79 as the result, which the authors believe to be true within ·06. Demarçay had given the atomic weight as about 151.—*Comptes Rendus*, cxxxviii, 628. H. L. W.

4. *The Use of Calcium Carbide as an Explosive in Mining.*—**Guédras** has described a method of utilizing the explosive force of acetylene for mining purposes. A sheet-iron cylinder is used as a cartridge. At its bottom are placed about 50 g. of granulated calcium carbide, and above this in a separate compartment is a sufficient amount of water to react with the carbide. There is also an air-chamber containing an electric fuse. The cartridge is placed in the hole to be exploded, the latter is closed with a wooden plug, and an iron rod attached to cartridge for the purpose of piercing the water compartment is struck, thus liberating the acetylene. After this has been disengaged for about five minutes, the mixture of air and acetylene is exploded. The explosion causes the rocks to fly about much less than would be expected, but they are thoroughly broken up.—*Comptes Rendus*, cxxxix, 1225. H. L. W.

5. *Silicon-fluoroform.*—The silicon compound, $SiHCl_3$, silicon-chloroform, is well known, and recently **Ruff** and **Albert**, by allowing the compound just mentioned to act upon tin tetrafluoride or titanium tetrafluoride, have succeeded in obtaining the corresponding fluorine compound. Silicon-fluoroform is a combustible gas which liquefies at atmospheric pressure at about $-90°$ and solidifies at about $-110°$. It is decomposed by water and alkaline solutions without change of volume, for the hydrogen produced by the decomposition is equal in volume to the original gas, as is evident from the following equations :

$$SiHF_3 + 3NaOH + H_2O = Si(OH)_4 + 3NaF + H_2 ;$$
$$2SiHF_3 + 4H_2O = Si(OH)_4 + H_2SiF_6 + 2H_2.$$

The preparation of the compound under consideration completes the series $SiHF_3$, $SiHCl_3$, $SiHBr_3$, and $SiHI_3$ of analogous halogen compounds.—*Berichte*, xxxviii, 53. H. L. W.

6. *Double Cyanides of Copper.* — A considerable number of these double salts has been prepared and studied by **Grossmann** and **von der Forst**. They are all cuprous salts, and contain lithium, sodium, potassium, rubidium, cæsium, as well as ammonium, calcium, strontium, and barium. Five different types of double salts were noticed ; for instance, omitting water of crystallization, I. $KCu_2(CN)_3$, II. $Rb_2Cu_2(CN)_4$, III. $KCu(CN)_2$, IV.

$Na_3Cu(CN)_4$, V. $K_3Cu(CN)_4$. The salts of type III were obtained in the largest number. It may be mentioned that all of these types occur among the known cuprous double chlorides.—*Zeitschr. anorg. Chem.*, xliii, 94. H. L. W.

7. *An Occurrence of Radium and Radio-active Earths.*—F. GIESEL has found that mud from Fango and soil from Capri possess an activity of about one one-thousandth of that of pitchblende, and that it is possible to extract radio-active products from them by chemical methods. For instance, from 40 kg. of the Capri soil about half a gram of barium bromide was extracted, which showed distinct spontaneous phosphorescence upon dehydration. In neither of the materials could uranium be detected.—*Berichte*, xxxviii, 132. H. L. W.

8. *N-Rays.*—E. GEHRCKE describes at length certain hallucinations which might arise in the investigation of the so-called N-rays. He finds that any object, the forefinger for instance, moved to and fro behind a phosphorescent screen produced a change in the light of the screen. The effect is not produced if an independent observer moves the object; and it is therefore a psychological one. The author believes that the phenomenon is analogous to many which arise at the extreme limit of vision. For instance one often believes that he sees a faint image while developing a photographic plate when no such image really exists. The author does not attempt to explain the photographs obtained by Blondlot and he remarks that in whatever way the phenomena of N-rays may be explained, Blondlot has rendered a service in calling attention to interesting phenomena.—*Physikalische Zeitschrift*, No. 1, Jan. 1, 1905, p. 7–8. J. T.

9. *Photography of N-rays.* — G. WEISS and L. BULL have failed to obtain such registration, and remark that Blondlot now concludes that the rays increase or affect visibility and not luminosity.—*Comptes Rendus*, cxxxix, Dec. 12, 1904, pp. 1028–1029. J. T.

10. *Spectra of Electric Discharges in Cooled Geissler Tubes.*—E. GOLDSTEIN describes the distribution of light and the spectra produced by suddenly immersing Geissler tubes in liquid air. The method appears to be of use in obtaining the spectra of metals in great intensity and with sharp lines. It also reveals a difference in the cathode light, according to the kind and nature of the cathode.—*Physikalische Zeitschrift*, No. 1, Jan. 1, 1905, pp. 14–17. J. T.

11. *The Dependence of the Ultra-Red Spectrum of Carbonic Acid upon Pressure.*—CLEMENS SCHAEFER concludes from his investigation on this subject that Arrhenius' theory in regard to the ice age is erroneous. The latter concluded from his figures that a diminution of the amount of carbonic acid in the earth's atmosphere would lead to a fall of temperature of the earth, and in consequence of diminished absorption there would be an increased radiation of heat from the earth into space. Thus an ice age might have been caused. Schaefer shows that the con-

clusion that variation in thickness of layer and variation in pressure have similar effect upon absorption is not justified. Changes of volume amount of $CO_2$ have no influence on the earth's temperature so long as the diminution of carbonic acid remains under 80 per cent of the former quantity.—*Ann. der Phys.*, No. 1, 1905, pp. 93–105. J. T.

12. *Electromagnetic Waves in the Visible Spectrum.*—Many attempts have been made to identify these waves with light waves. **FERDINAND BRAUN** forms suitable resonators or "Gitters" by deflagrating very fine wires stretched on glass plates; and then observing changes of polarization by means of suitable optical devices directed upon the particles of finely divided metal. According to the electromagnetic theory these "Gitters" should allow little light through if the arrangements of the particles are parallel to the electric vector, and much if they are perpendicular to it. The author believes that his photographs show a complete analogy between Hertz waves and optical waves. He shows also that the method he employed is of importance in mineralogical work.—*Ann. der Phys.*, No. 1, 1905, pp. 1–19. J. T.

13. *Damping Galvanometer Deflections.*—W. **EINTHOVEN** continuing his investigations on his new galvanometer, which consists of a silvered quartz fiber stretched in a strong magnetic field, finds that a condenser attached to the terminals of the fiber is of great use in bringing the oscillations to rest even when they are extremely rapid. It is believed that the method will be of great advantage in acoustical investigations and also in physiological work.—*Ann. der Phys.*, No. 1, 1905, pp. 20–31. J. T.

14. *Possible variation in Solar Radiation.*—The report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1904 (noticed on p. 260), contains in the statement of the work accomplished at the Astrophysical Observatory, under the charge of C. G. Abbot, a further discussion of the possible variability of the sun first rated in the report of the year preceding. We quote the following paragraphs:

"Notable progress has been made with the researches you have initiated on the amount of solar radiation and its absorption in the solar envelope and in our atmosphere. Within the last seventeen months three independent kinds of evidence have been collected here, pointing toward the conclusion that the radiation supplied by the sun may perhaps fluctuate within intervals of a few months through ranges of nearly or quite 10 per cent, and that these fluctuations of solar radiation may cause changes of temperature of several degrees centigrade nearly simultaneously over the great continental areas of the world. Further evidence must, however, be awaited to verify this important conclusion.

The three kinds of evidence referred to are as follows: First, on all favorable days the 'solar constant' of radiation outside our atmosphere has been determined here, and changes of about 10 per cent in the values obtained have been found which cannot be attributed to known causes. Second, the solar image formed by

scope has been examined with the spectro-
mine the absorption of radiation within the
lf. If we grant for argument's sake that the
ion outside our atmosphere fluctuates rapidly
then as you have observed, the cause of this
easonably be a variability of the temperature
ody as the sun itself, but must rather be in a
ption of a more or less opaque envelope sur-
Accordingly the two researches I have men-
ly associated, for if we find a considerable
f solar radiation outside our atmosphere we
sponding decrease in the absorbing power of

e of the most notable results of the year's
eptember, and October, 1903, the observa-
nstant' of radiation indicated that the rate
nt 10 per cent below that observed in Feb-
other hand, measurements of the absorption
indicated considerably less absorption in
n September, 1903.
vidence of change in solar radiation is
he temperature of the North Temperate
the Internationale Dekadenberichte pub-
Marine Deutsche Seewarte, and received
gh the kindness of the Librarian of the
Bureau. This publication gives the
. M. for each ten days at each one of
ns distributed over the principal land
te Zone, and for about ninety of these
the normal temperatures for the same
g the mean of many years. From
mputed here the temperature depar-
January 1, 1903, and these are com-
mpanying chart, Plate VII,* with
nt made in 1903. It will be seen
fall of solar radiation in March,
ure occurred, which would be a
. It has been shown here, in
of radiation, that 10 per cent
produce more than 7°·5 C. fall
at several causes, notably the
nt so great a change of tem-
nporary diminution of solar
tion. The observed fall of
e of the land areas of the
. 1903, seems to be there-
s of solar radiation.
the first six months of

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iation of the Solar Radia-

1904 few measures of the 'solar constant' worthy to be compared with the series of 1903 have been obtained, but taking the best of the measures it appears that high values of solar radiation in February, 1904, and lower ones in the subsequent months are indicated, as shown in Table II, given below. This appears to be in general accord with the mean temperature observed over the North Temperate Zone, except that it seems probable that the solar radiation was high in January as well as February, but the lack of good observing weather prevented our recognition of it."

The importance of this subject is remarked upon in its bearing upon forecasts of temperature, in case further research serves to confirm the indications now obtained as to a general parallelism between measures of solar radiation and terrestrial temperature. For this work, however, a better station for observation than Washington is needed.

15. *Terrestrial Magnetism. Results of Magnetic Observations made by the Coast and Geodetic Survey between July 1, 1903, and June 30, 1904;* by L. A. BAUER. Appendix No. 3, Report for 1904. Washington, 1904.—This report* contains the usual detailed statement of magnetic observations made in the United States and outlying territories during the year ending June 30, 1904; an interesting feature is the introduction of observations made at sea by the Survey vessels, this is a new departure begun in February, 1903. In the introductory summary of results reached some interesting notes are made, particularly in regard to the changes of magnetic declination in Louisiana. We quote some paragraphs:

"The results of this detailed work in Louisiana have been extremely interesting. First, it has been clearly demonstrated that there was a reversal in the expected course of the secular variation which took place about 1898. Past observations made in the vicinity of New Orleans show that the magnetic declination, which is east, reached a maximum amount of about 8¾° near the year 1830. It then began to diminish, and, in accordance with the laws of the secular variation pertaining north and east of the agonic line, i. e., in the Atlantic States, where west declination is known to be increasing at present on the average about three minutes per year, a turning point was under ordinary conditions not to be expected before some time about the middle of the present century. Instead, however, it was reached about 1898, so that east declination reached a minimum value of 5½° in about seven decades after a maximum value—the shortest interval between a maximum and a minimum value thus far revealed anywhere on the earth. East declination is now increasing in Louisiana at the rate of about one and one-half to two minutes per annum. The total change between maximum and minimum at New Orleans, as above stated, was about 3¼°.

The early reversal produced a larger annual change between the years 1860 and 1870—about six minutes—than has generally been experienced in the United States, although elsewhere, as, for example, England, such large annual changes and even greater ones occur. Values of the magnetic declination secured four to five decades ago, if referred to the present time with the aid of secular change values as were expected, in accordance with the experience in other parts of the United States, would be in error one-third to one-half degree.

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* See also p. 261.

Observations in other States near Louisiana show that this change in the course of the secular variation is manifesting itself in greater or less degree, according to locality, likewise in these States. How permanent the present change may be, i. e., whether it will continue for but a comparatively short period, so that before long another reversal may be expected, after which east declination will begin to diminish once more, can not be stated at present.

The magnetic survey of Louisiana has revealed other most interesting features, as shown by the lines of equal magnetic declination, dip, and horizontal intensity, drawn in conformity with the observations. There were noticed marked relations with well-known physiographic features. The curvatures and bendings of the lines of equal magnetic declination appear to conform with courses of principal steams and shore lines of certain bodies of water. Also a marked difference manifested itself in the general direction of these lines in the middle of the southern part of the State, just where there is a dividing line between the newer and older geological formations.

It is especially interesting that the irregularities in the distribution of the earth's magnetism, as exhibited by the three sets of lines, occur chiefly in the regions of the alluvial deposits brought down by the Missisippi River. Owing to these irregularities the compass needle is deflected from the direction it would ordinarily have assumed by amounts varying from about 0°·1 to 0°·5. They are not local disturbances of such amount which ordinary instruments would readily reveal, but they are of such a magnitude as only approved instruments and methods would indisputably expose. This point can not be emphasized too strongly for the sake of geologists who undertake to discover relations between magnetic disturbances and geological formations, employing crude instruments, and using imperfect methods.

Quite likely these irregularities are to be referred to small local deposits of iron ore brought down from the upper States by the Mississippi River."

16. *An Introduction to the Study of Spectrum Analysis;* by W. MARSHALL WATTS. Pp. vii, 325, 8vo. London and New York, 1904 (Longmans, Green & Co.).—The first impression from a hasty inspection of this work is the extraordinary variation in the character and value of the numerous illustrations contained in it. We recognize some cuts which are familiar in popular works on spectroscopy from as early a date as 1870, and which might have been omitted even then with profit to the reader. A number of those illustrating the very primitive treatment of the

optical theory of the spectroscope are subject to this criticism; and fig. 15, intended to show the path of the light through a powerful prism spectroscope, could hardly be modified so as to give more hopelessly false ideas as to the optical principles involved. A critical reading shows an analogous lack of uniformity in the unexpected relative importance attaching to the different topics treated. Probably few spectroscopists would approve the ratio of eight pages devoted to absorption spectra to only two appropriated to the explanation and application of Doppler's principle. A single page is given to the subject of spectroscopic binaries, of which *o* Ceti and *β* Cygni (with relative magnitudes reversed) are cited as examples. It would be difficult to imagine errors which would be more confusing to a beginner. This is immediately followed by more than six pages on the spectra of comets. Another peculiarity is an utter lack of system in the orientation of cuts representing spectra. In many, the wave-lengths decrease from left to right, while in the others the reverse order is employed; nor is it always easy to tell, either from the figure or from the text, which arrangement is selected.

On the other hand, there are features which will make the book a welcome addition to every scientific library. The copious references to sources and the extended tables of spectra at the end of the volume will certainly prove conveniences. Then, too, the chapter on the Michelson Echelon spectroscope is so satisfactory that one wonders why the important theory of the concave grating is wholly neglected. C. S. H.

17. *The Reflecting Telescope.* From Vol. XXXIV of Smithsonian Contributions to Knowledge.—This publication consists of two parts, the first of which is a reprint of the celebrated paper by Professor Henry Draper, On the Construction of a Silvered Glass Telescope, published in 1864 in Vol. XIV of the same series. This is so well known to all amateur and working opticians that a review of it here is quite unnecessary. The second part, of nearly the same length, bears the title, On the Modern Reflecting Telescope and the Making and Testing of Optical Mirrors, by George W. Ritchie of the Yerkes Observatory. This is a highly interesting description of the refined methods which have been gradually introduced during the forty years which have lapsed since the appearance of the earlier paper, illustrated especially by the experience of its author in constructing 24- and 60-inch parabolic mirrors in the optical shop of the Yerkes Observatory. The frontispiece is an enlargement of the admirable photograph of the central portion of the Great Nebula in Andromeda, taken by Mr. Ritchie with the 24-inch mirror. A comparison of the illustrations of the two papers—both of the highest excellence attainable at their respective periods—is most instructive. C. S. H.

18. *An Introduction to the Theory of Optics;* by ARTHUR SCHUSTER. Pp. xv, 340. London, 1804 (Edward Arnold).—This is a notable addition to the literature on optics. The first

two hundred pages are occupied with a general description of the phenomena of optics with their mathematical theory. Chapters IV, V and VI, on interference of light, diffraction, and diffraction gratings, respectively, are especially good. The chapter on the theory of optical instruments, however, leaves much to be desired; the theory of the microscope is not touched upon, and a theory of the telescope, which leads to the conclusion that a magnification of eight to the inch of aperture of the objective quite exhausts its resolving power for an eye free from spherical aberration, is necessarily erroneous.

Part II, on modern theories of light, of dispersion and absorption, and of the relations of optical to electromagnetic phenomena, containing all that is very recent in optical science, is of greater value and interest. A careful reading of this portion is certain to be profitable to every student of physics. The treatment of Talbot's Bands (p. 329) may be cited as specially interesting and suggestive.

The illustrations of the work are not wholly satisfactory, with the exception of its two plates which are reproductions of direct photographs of interference phenomena. Unfortunately, the references in the text to these plates contain many errors which would prove very confusing to one not already familiar with the phenomena. We may add that the first figure on Plate I, showing the interference bands formed by a biprism, owes its irregularities to a defective prism, not, as is asserted in the text, to the periodic nature of light itself. C. S. H.

19. *Das Elektrische Bogenlicht; seine Entwickelung und seine physikalischen Grundlagen;* von W. B. VON CZUDNOCHOWSKI. Erste Lieferung, pp. viii, 98. Leipzig, 1904 (S. Hirzel).—The first part of this work upon the electric arc light was issued some months since and is largely devoted to the physical side of the subject. The entire work is to be published in six similar parts, and from what we have before us may be expected to satisfy all demands as to fulness of description and illustration.

## II. GEOLOGY AND MINERALOGY.

1. *A Treaties on Metamorphism;* by CHARLES RICHARD VAN HISE, U. S. Geological Survey, Monograph XLVII, 1286 pp., 13 pl., 32 figs.—Professor Van Hise's Treatise on Metamorphism will undoubtedly take rank as one of the most important single publications ever issued by the Geological Survey. The volume is the outcome of a life-long study in the province of metamorphic geology. Partial views have been published in his earlier papers, and the ground work of metamorphism has, of course, been gradually established through the labors of many leaders in geology during the past century. Nevertheless the subject is doubtless indebted to Van Hise more than to any other one individual for its reduction to an exact science. In the present treatise a highly successful attempt has been made to arrange the

phenomena of metamorphism in order and to show how they are throughout the expression of chemical and physical laws operating within the crust of the earth.

The earliest stage of science is largely descriptive, qualitative and speculative. The branch of metamorphic geology may now be said to have fully passed through such a preliminary stage and to have entered upon its final development. Although many able works have appeared in the past this treatise must be looked upon as the landmark of a new era, a starting point from which further studies will largely take their departure. Following these introductory statements the volume itself may be described.

In the introductory chapter it is shown that a great difficulty in studying metamorphism arises from the fact that many of the changes take place under conditions which cannot be directly observed, so that the forces and agents accomplishing certain results must be inferred from the nature of the results. This method is directly the opposite of that which has usually been applied to the elucidation of surface geology, and this fact gives the peculiar difficulty to the deeper problems of metamorphism and has retarded its development to a period later than that of any other branch of the science.

Under metamorphism is embraced not only the changes which take place in the deeper parts of the lithosphere but surface alterations as well, so that the treatise covers a large part of the ground of the older treatises on chemical and physical geology.

It appears that the processes of metamorphism, using the term in this inclusive manner, come under surprisingly few heads. The upper zone, characterized by hydration, oxidation, carbonation, resulting in expansion of volume and production of heat, tends to break down complex mineral molecules into a few of relatively simple composition and, following the analogy of the term of katabolism in biology, the zone is called the *zone of katamorphism* ("kata" meaning tearing down). This zone is divided into a *belt of weathering* extending to the level of ground water and below this a *belt of cementation*, within which is deposited much of the silica and other substances carried downward from the belt of weathering.

The zone of katamorphism corresponds roughly with the zone of fracture. Below this pressure due to gravity becomes the dominant factor in reactions. Complex compounds whose formation is attended by contraction of volume result from more simple ones. The reactions are characterized by a tendency to dehydration and decarbonation where water or carbonic acid is present. Again, following the analogy from biology, this zone, in which complex molecules are built up, is named the zone of anamorphism (from "ana" meaning a "building up"), and corresponds in general with the zone of flowage, the one term expressing the character of the chemical and mineralogical changes, the other the character of the mass deformations.

In both zones it is believed that the total reactions involve the liberation of heat, in the outer zone from chemical reaction, in the inner from reduction of volume; and thus metamorphism conforms to the apparent law of the universe of dissipation of energy.

Chapter II treats in detail of the forces of metamorphism; chemical energy, gravity, heat, and light. Chapter III of the agents, which are gaseous and aqueous solutions and organisms.

Of great use to the working geologist and mineralogist is chapter V, which treats individually of the geological relationships, genesis and alterations of each of the rock-making minerals. The alterations are ordinarily such as take place in the zone of katamorphism, but the author points out that upon the altered materials being brought again into the zone of anamorphism the reactions are reversible and, provided that the results of decomposition are present in suitable proportions, the original mineral may be reproduced. Some of the more complicated reactions have been written out chemically for the first time, and, as pointed out by Van Hise, must be looked upon as first approximations and suggestive for further study.

The following three chapters, VI, VII, VIII, treat in detail of the belt of weathering, the belt of cementation and the zone of anamorphism. In regard to the belt of weathering besides a statement of the laws governing the changes a number of new features are developed, but special emphasis is placed on systematization under laws of physics and chemistry, of a vast number of facts already known.

In chapter VIII, among other matters are treated the meaning and method of rock flowage, the generalization being arrived at that rock flow is mainly accomplished through continuous solution and deposition, that is, by recrystallization of the rocks through the agency of the contained water, the rocks throughout, with the exception of an inappreciable amount which at the moment is in solution, being crystallized solids.

The student of metamorphic geology is expected as a matter of course to study carefully the entire monograph and a review should hardly be written for him, but rather for the general student of geology.

To such, perhaps, the most interesting chapter is the eleventh, upon *the relations of metamorphism to the distribution of the chemical elements*, and a more extensive review of this chapter will therefore be given.

Metamorphic processes operating upon the lithosphere have redistributed the elements of the original igneous rocks tending to segregate them into the several groups of sedimentary rocks, the hydrosphere and atmosphere, this redistribution concerning many large questions of geological theory. The author states,—"So far as practicable redistribution is dealt with in a quantitative way, . . . made more with a view of stating the various problems which in the future will undoubtedly be satisfactorily treated quantitatively rather than with the belief that the calculations given even approach accuracy. Indeed this chapter is no more than an attempt to blaze a trail in the wilderness."

The author then considers the average composition of the lithosphere, the sedimentary rocks, the hydrosphere and atmosphere, using the work of F. W. Clarke, Dittmar and Farrington. The sedimentary rocks with certain portions of the hydrosphere and atmosphere, if recombined should give the average composition of the igneous rocks from which they were originally derived, and as a first approximation the shales are estimated at 0·65, the sandstones 0·30, and the limestones 0·05 of the sedimentary rocks; and the average thickness of the latter upon the surface of the continents which have always remained within the zone of katamorphism is estimated at two kilometers, this being less than has usually been estimated.

The results indicate that this relative proportion of the sediments must be in the neighborhood of the truth. In regard to the thickness of the sediments, however, Van Hise is inclined to think that even the moderate estimate of two kilometers may be too great. By assuming a smaller thickness, however, the character of the results would not be changed but only the absolute amounts of the surpluses and deficiencies. From these data some surprising results are obtained. To oxidize the ferrous iron of the igneous recks to the ferric state in which it is usually found in the sediments would require 35 per cent of the oxygen now in the atmosphere. The further oxidation of the metals and the sulphur united as sulphides in the original rocks would require twice the oxygen now in the atmosphere. Further quantities have been consumed in the formation of nitrates. "In summary it appears that the chief certain source of oxygen for the atmosphere is the reduction of carbon dioxide by vegetation and the burial of a part of this vegetation in the earth. This source is vast in amount. On the other hand . . . the oxygen consumed during geological time . . . has been enormous. It probably vastly exceeds the amount which has been liberated to the atmosphere by the reduction of carbonic acid through plants."

"If this conclusion be correct, such wild guesses as those of Koene and Phipson, that the carbon dioxide of the original atmosphere greatly exceeded the oxygen and that the proportions of these elements have been reversed in consequence of the reduction of carbon dioxide by organic matter, are wholly unwarranted."

Under *sulphur*, it is shown that the proportion of sulphur in the secondary rocks and ocean is more than four times as great as in the original igneous rocks. It is thought highly probable that the discrepancy is largely explained by the actual escape of much sulphur as a gas during periods of volcanism, the igneous rocks containing only the residual sulphur which separated as a sulphide when the magma crystallized. The same explanation probably applies to a similar excess of carbon and chlorine.

It is found that silica shows an excess of 3·2 per cent in the secondary rocks and alumina a deficiency of 3·7 per cent. The author suspects that this discrepancy is largely due to errors in the determination of the silica and alumina in the analyses of shales.

Some of the general conclusions in regard to carbon are already somewhat familiar through the work of Chamberlin and others, the amount which is locked up in the sedimentary rocks being estimated at many hundred times that contained in both the atmosphere and hydrosphere.

"The chief processes which abstract carbon dioxide from the atmosphere are those of carbonation and the building up of carbonaceous deposits. All the replenishing processes, including the reversing processes of silication and the oxidation of buried carbon compounds, have been barely able to keep a minute portion of the carbon dioxide in the atmosphere. . . . It is probable however that the work of man, especially during the last half century, has returned a great volume of carbon dioxide to the atmosphere by the artificial oxidation of carbonaceous material, and thus has reversed the average of the processes of nature, which plainly appear to have caused depletion of the carbon dioxide in the atmosphere. In consequence, at the present time the amount of carbon dioxide in the atmosphere may be increasing rather than decreasing."

In treating of the alkalies it is shown that the amount of potassium in the sedimentary rocks and the ocean agrees fairly well with the proportions in the original igneous rocks. In the case of sodium, however, there is a remarkable deficiency in the sedimentary rocks, and even when the salt of the ocean is added the total sodium reaches a proportion not more than one-third of that in the original rocks.

"It is, therefore, plain that we must turn to some other direction to account for the great deficiency of sodium in the ordinary sedimentary rocks. The natural direction to which to turn is to the salt deposits of the world. . . .

"From the foregoing it appears highly probable that we must look to the salt deposits and to the alkaline deposits of arid regions to explain the great deficiency of sodium in the ordinary sediments rather than to the ocean. If this conclusion be correct, calculations upon the age of the earth have no value which are based upon the derivation of salt from the land through weathering processes and its accumulation in the sea, and which ignore or place as relatively unimportant the salt deposits of the land."

The final chapter of 240 pages deals with ore deposits and is an amplification and further systematization of the papers already published by the author in the Transactions of the American Institute of Mining Engineers. Special emphasis is placed on the application to ore deposits of all laws developed for metamorphism in general.

The foregoing pages of this review have served to give some idea of the breadth and depth of this treatise. In conclusion it may be said that the general student will find here in the most systematized and digested form a vast mass of facts and principles dealing with chemical and physical geology. All students of geology should gain some familiarity with its contents, and to the specialist in metamorphism it must become a volume of constant study and reference. J. B.

2. *The United States Geological Survey,* Twenty-Fifth Annual Report, 1903–'04, 371 pp., 25 pls., 2 figs.—The United States Geological Survey has reached its quarter-century anniversary and the director gives a brief outline of the results accomplished during the twenty-five years of the Survey's existence. A complete topographic map of 929,850 square miles of the United States, including Alaska, has been made during this time, which amounts to 31 per cent of the area of the country, excluding Alaska. The Survey has been particularly helpful in investigation of the origin and geologic relations of ore deposits; and the results of this work in Leadville and the Lake Superior region are alone sufficient to justify the generous appropriation now granted by congress. The first appropriation for the Survey amounted to $106,000. The total appropriated in 1903–'04 was $1,377,820. During recent years the qualitative standard of the work has been much raised; greater accuracy and higher literary quality characterize the recent papers published by the Survey. Eleven states now coöperate with the government in topographic surveys, and topography still claims the larger share of the annual appropriation.

The section of Pleistocene Geology has been renamed the section of Physiography and Glacial geology and placed in charge of G. K. Gilbert. This new division is in distinct recognition of the geographical aspects of geology, and the importance of ice as a geologic agent. The work in Alaska has received greater attention than ever before, and the geographic and geologic publications in that section show the development of one of the most remarkable pieces of scientific exploration ever attempted. The reclamation service reports rapid advance in many of the western states, and during the year actual construction was begun on the Salt River project in Arizona and the Truckee-Carson project in Nevada. The division of chemistry and physics is conducting important researches along new lines and it is gratifying to see that the work is sufficiently recognized as to receive largely increased appropriations.

3. *Geology of Perry Basin in Southeastern Maine;* by GEORGE OTIS SMITH and DAVID WHITE. United States Geological Survey, Professional Paper No. 35, 102 pp., 6 pls.—The Perry Basin has excited the interest of geologists ever since the formations were first described by Jackson in 1836, and a great deal of difference of opinion has existed regarding the origin and age of the strata here exposed. The formation is now shown to be "distinctly Devonian and probably Chemung." It consists of

brownish conglomerates with interbedded lavas lying unconformably on earlier formations.

The present investigation was undertaken jointly by the United States Geological Survey and the State of Maine in a search for coal, and ten days of field work were sufficient to amply prove that there is no geological evidence to support the belief that coal exists in this region. This investigation brings clearly to light the value of geologic work. For the last seventy years there has been a persistent belief that coal could be obtained in the district about Passamaquoddy Bay, and shafts and drill holes have been put down at considerable expense at different times. This persistent myth has led the public astray and shows how ready the average man is to accept favorable rather than unfavorable reports. At a small expense the question of coal in Maine has been settled once for all and might have been equally as well settled fifty years ago if it had been so desired.

In addition to newly discovered plant remains Dr. White has studied the collections in American museums, and his present descriptions and figures constitute a fairly complete study of the Perry fauna.

4. *Preliminary Report on the Arbuckle and Wichita Mountains of Indian Territory and Oklahoma;* by Jos. A. TAFF: with an appendix on *Reported Ore Deposits;* by H. FOSTER BAIN. United States Geological Survey, Professional Paper No. 31, 93 pp., 8 pls., 1 fig.—Very little has been heretofore known regarding these interesting mountain areas lying west of the main Ozark uplift. The Arbuckle Mountains consist of a great thickness of rock chiefly limestone, from Middle Cambrian to Devonian, overlaid by Carboniferous conglomerates, shales, and sandstones. The central part of the district, unconformably beneath the Cambrian strata, is a mass of granite, granite porphyry, diabase, and associated crystalline rocks. The mountains date from Middle Carboniferous, but were worn down before the end of Carboniferous time. Folding and faulting occurred during all Carboniferous, and there is no record of sedimentation between the Permian and Cretaceous. Peneplanation occurred in Cretaceous time and also in Tertiary, when the region was reduced practically to sea-level. The structure of the mountains has been worked out in detail and shows a number of well-developed anticlines and synclines.

The Wichita Mountains are a new field of study and consist of a collection of mountains, hills, and knobs extending for a distance of 65 miles. The mountain region is symmetrical in general outlines; but the arrangement, size, and forms of individual masses are remarkably various and rise from the nearly level smooth plain of the "red-beds" as so many islands. The mountains proper and most of their outlying groups consist of granite, granite porphyry, and gabbro. These igneous rocks are separated into more than 250 detached areas, and this archipelago-like arrangement of the granite peaks seems to indicate that but a small part of the igneous core of the Wichita uplift is now exposed. The rock section of the Wichita Mountains is almost an exact reproduction both in stratigraphy and structure of the Arbuckle Mountain uplift, and the epochs of its stratigraphic history probably also correspond with those in the mountains to the east.

5. *The Oldest Sedimentary Rocks of the Transvaal.*—In a recent paper by FREDERICK H. HATCH, published in the Transactions of the Geological Society of South Africa, vol. vii, pt. 3, attention is called to the discovery of metamorphosed sediments of earlier age than the Witwatersrand series. The rock is variable in character. One of its stricking features in the Mt. Marais district is the presence of "knotted" schist containing andalusite and ottrelite. This early formation has been named the Swaziland series and, with its intrusive granite, is ascribed to the Archean system. Swaziland beds occupy the same relative position as the Malmesbury beds of Cape Colony.

A paper by E. J. T. JORISSEN, read December 12th, before the Geological Society of South Africa, gives a detailed description of the granites which are intruded in the Swaziland beds, and underlying unconformably the Witwatersrand.

6. *Maryland Geological Survey. Miocene*, text, pp. i–clv, 1–543; volume of plates, x–cxxxv. The Johns Hopkins University, 1904.—These two splendid volumes treat of the stratigraphy and life of the Miocene deposits of Maryland. The stratigraphy is described by Clark, Shattuck, and Dall. The fauna and flora are described in detail and illustrated by excellent drawings, as follows: The plants, by Hollick and Boyer; vertebrates, by Case and Eastman; the bivalves, by Glenn; the other Mollusca, the brachiopods, and most of the Crustacea, by Martin; the ostracods and bryozoans, by Ulrich and Bassler; the echinoderms, by Clark; the corals, by Vaughan; the foraminifers, by Bagg. The number of fossil species is large, as 652 are described.

The State Geologist reports that the "most important contribution to the interpretation of the Maryland Miocene deposits which has been hitherto made" is by Dr. Dall. On pages cxxxix–clv, Dall discusses "The relations of the Miocene of Maryland to that of other regions and to the recent fauna." The Maryland Miocene is divided into Calvert, Choptank, and St. Mary's formations. "One-third of the molluscan fauna of the Maryland Chesapeake is peculiar to it. Ten per cent survive to the present fauna."

"The temperature conditions governing the fauna of the Maryland Chesapeake were those of the temperate rather than the boreal or subtropical faunas of the present coast; and . . . the temperature of the Chesapeake embayment was on the whole somewhat warmer than at present."

"In a general way, allowing for local peculiarities, the Miocene fauna of North Germany compares well and agrees closely with that of Maryland, while the Mediterranean Miocene finds a closer analogue in the more tropical fauna of the Duplin beds of the Carolinas."

These volumes should be in the hands not only of stratigraphers and paleontologists, but of all teachers of historical geology as well, for here is given not only a detailed description of the Maryland Miocene stratigraphy and its preserved organic remains, but also the relationship of these faunas to those of other areas of North America and of Europe. The State of Maryland is to be congratulated on its able and active survey staff, under the efficient leadership of Professor W. B. Clark. Among state surveys it stands second, ranking next to that of the rich state of New York. C. S.

7. *Palæontologia Universalis.* — The third fasciculus of this important republication of old or obscure species of fossil organisms has arrived. These three parts treat of 75 species, figured and described in 161 sheets. This completes the first annual subscription, which is eight dollars. The first fasciculus of the second series will soon appear, and subscriptions should be sent to G. E. Stechert and Co., 129–133 West 20th street, New York City. The editorial work is in the hands of D.-P. Œhlert, of Laval, France, Secretary to the International Commission appointed by the International Geological Congress, at its eighth meeting. C. S.

8. *On the Melting Points of Minerals.* — M. A. BRUN has recently published a second memoir on the subject of the fusion of minerals, which was first discussed by him in 1902.* The object of the present investigation has been to establish the melting point of the feldspars and some other important minerals (leucite, chrysolite, wollastonite), both in the crystalline and glassy states. The results now obtained are summarized by the author as follows :

"The present work will serve to control scientifically the values previously given, and, also, to establish the melting points of the *colloids*, which have the same percentage composition as the crystals.

The measures have been taken with the help of the calorimeter. A large block of platinum was used as thermometer and Viole's rule was used for the calculation of the temperature.

The results of these experiments prove that the figures published in 1902 are exact. They therefore agree with the figures given for the *crystals*. It is shown, moreover, that in the complete thermic study of the silicates, the following points should be determined.

(*a*) The melting temperature of the *crystal*. (*b*) The melting and softening temperature of the *colloid* (glass) which has the same percentage composition. (*c*) The temperature needed to bring about the crystallization of colloids. (*d*) The temperature of the point of the agglomeration into a mass of powder such as: chrysolite, kaolin, zircon.

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* Arch. des Sc. phys. et nat. (4), xiii, April, 1902. See also the paper by Day and Allen in the February number of this Journal.

There are great differences between these various points. Between *a* and *b* there can be several hundred degrees of difference."

The following may serve as illustrations of the numerical results obtained.

For *anorthite* from Miyake Idsu, Japan, a crystal remained for a long time unaltered at 1350°; at 1425° it still preserved its cleavage, and 1490° was obtained as the most probable point of the destruction of the crystalline structure. With anorthite of absolute purity, prepared for the purpose, the following values were obtained:

| Relation of $\frac{c'}{c}$ | Temp. of destruction of the crystal | Capacity in calories of 1 kilo of the fused mineral |
|---|---|---|
| 7·07 | 1544° | 451·2 |
| 7·1 | 1547° | 453·6 |
| 7·128 | 1550° | 455·9 |
| 7·19 | 1562° | 456·8 |

For anorthite glass the following points were also obtained:

No. 2, Minimum temperature of the deformation of the glass, 1083°, 1110°.

No. 3, Temperature at which the glass begins to be clouded, 1144°.

No. 3 *bis*, Temperature at which the glass becomes crystalline, labile point, 1210°.

Temperature at which the crystallization has the appearance of being rapid, 1250°.

With *leucite*, at a temperature of 1430° the edges of the crystal were rounded and the faces vitrified though, as a whole, it did not lose its shape. At 1470°, though still preserving its form, it was softened so that it could be easily flattened out by the pincers. At 1500° the glass commenced to form and was complete at 1600°.

For *chrysolite* the point of fusion was too high to allow of being determined accurately but was estimated to be about 50° below that of platinum; 1730° was taken as the probable temperature. *Wollastonite* from Auerbach (monoclinic in crystallization) was liquified at 1366° to a glass which quickly assumed a hexagonal crystalline structure. The artificial hexagonal mineral fused to a fluid, transparent glass at 1515°.

9. *Mineral Resources of the United States. Calendar year 1903.* DAVID T. DAY, Chief of Division of Mining and Mineral Resources. 1204 pp. 8vo. Washington, 1904 (U. S. Geological Survey, Charles D. Walcott, Director).—This annual volume of the Geological Survey devoted to the Mineral Resources of the United States, like its predecessors, contains a vast amount of useful and important information. This is made the more valuable from the fact of the admirable promptness with

which it is issued. Much of the matter, further, has already been in the hands of those interested in the form of separately issued pamphlets for the different chapters. The geologist-in-charge states that the report for the calendar year 1904 is already in course of preparation.

10. *Elements of Mineralogy, Crystallography and Blowpipe Analysis;* by ALFRED J. MOSES and CHARLES LATHROP PARSONS. Third enlarged edition. Pp. vii, 444, 8vo. New York, 1904 (D. Van Nostrand Co.).—The new edition of this convenient and useful text-book retains all the good features of the former issues, with some important changes and additions. The crystallography has been rewritten, various changes made in the part devoted to descriptive mineralogy, and the whole brought up to date, so far as statistics and similar matters are concerned. Numerous half-tones from photographs of mineral specimens are introduced; they are in some cases very satisfactory, but share the limitations of such illustrations in general.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of S. P. Langley, Secretary of the Smithsonian Institution for the year ending June 30, 1904.* Pp. 1–99. Washington, 1904.—The functions of the Smithsonian Institution are widely varied, including, besides publications and special work of research and exploration, the constantly expanding department of International Exchanges, the National Museum, the National Zoological Park, the Astrophysical Observatory and the Bureau of American Ethnology. This fact gives peculiar interest to the advance report of the Secretary in which the results accomplished for the year are enumerated. Among other points is to be noted the removal of the remains of James Smithson from Genoa, and their deposition in the Smithsonian Institution in the early part of 1904. Another point of interest is the beginning of the new Museum building for which ground was broken June 15, 1904. The new building will be some 551×318 feet and will give a floor area of 9½ acres in its four stories. Some of the results obtained in the Astrophysical Observatory are given on p. 246 of this number.

The Bureau of American Ethnology, W. J. McGee, Acting Director, has recently issued Parts 1 and 2 of the 22d Annual Report. Of these Part 1 (pp. xliii, 320) contains the report of the Director to the Secretary of the Smithsonian Institution; also a paper by Jesse W. Fewkes (195 pp., 70 plates) on Pueblo Ruins; and one by Cyrus Thomas (pp. 197–305, 12 plates) on Mayan Calendar Systems. Part II (372 pp., 9 colored plates) is devoted to a memoir on the Hako, a Pawnee Ceremony by Alice C. Fletcher, assisted by James R. Murie.

2. *Report of the Superintendent of the Coast and Geodetic Survey, showing the Progress of the Work from July 1, 1903 to June 30, 1904.* 774 pp., with numerous plates and four maps.

**Washington, 1904 (Department of Commerce and Labor).**—The annual volume from the Coast and Geodetic Survey contains the general report of the Superintendent, Mr. O. H. Tittmann, for the year ending June 30, 1904, with special statements from the various assistants and inspectors. A series of nine Appendixes follow, giving the details of operations in the office and field, results of magnetic observations, of work done on telegraphic longitudes, on cotidal lines for the world and other subjects.

From the report by Mr. L. A. Bauer upon the results of the magnetic observations, we have quoted on another page (p. 248). The Superintendent notes the interesting fact of the completion of the determination of the difference of longitude between San Francisco and Manila, and details of the work are given by Assistant Edwin Smith in Appendix 4. It is notable that the finally accepted value of the longitude of the Cathedral dome at Manila differs but $0^{s}\cdot006$ from that determined by officers of the U. S. Navy in 1881–82.

3. *The Scottish National Antarctic Expedition.*—The second Antarctic voyage of the "Scotia" has produced some interesting results. The Argentine government has agreed to take over the meteorological and magnetic observatory in the South Orkneys, established by the first Scottish expedition. The newly-discovered part of the Antarctic continent has been named Coatsland, in 74°1′ south, 22°0′ west. Some very rich hauls were made in 1410 fathoms of water in 71°22′ south, 16°34′ west, no less than sixty species of animals being obtained. One of the most interesting results of the exploration is the discovery that soundings made by Ross, and which are represented on practically all maps, are in error. Instead of a sounding of "4000 fathoms, no bottom" a sounding of 2660 fathoms was obtained, and the sea, likewise, is shown to be of much less extent than was supposed. Data were collected at the South Orkneys for a detailed map of Laurie Island; a continuous hourly meteorological record was kept for nine months; botany and geology were investigated, and an extremely rich shallow water fauna was collected. In the South Atlantic a somewhat deeper channel has been demonstrated between the Falkland Islands and the South Orkneys, and farther to the east the ocean maps have been materially changed by the discovery of a large southern extension of the Middle Atlantic ridge to the south of Gough Island.

4. *National Academy of Sciences.*—Vol. V of the Biographical Memoirs has been recently issued; it contains notices of the following gentlemen, former members of the Academy: Joseph Henry, John Edwards Holbrook, Louis François de Pourtalès, Augustus A. Gould, Henry A. Rowland, Theodore Lyman, Matthew Carey Lea, Francis A. Walker, John G. Barnard, James E. Keeler, James Hadley, Henry B. Hill, Sereno Watson, Robert E. Rogers. Each notice is accompanied by a portrait and signature.

5. *The American Museum Journal.*—The January number of this publication is largely devoted to a well illustrated paper by

W. D. Matthew on Fossil Carnivores, Marsupials and small Mammals in the American Museum of Natural History in New York City. Dr. E. O. Hovey also gives an account of the three Cape York meteorites, brought from Greenland by Capt. Peary, the two smaller ones in 1895 and the immense "Ahnighito" in 1897; these are now exhibited at the American Museum. The dimensions of the largest masses are: length, 10 ft. 10 in.; height, 7 ft. 2 in., and thickness, 5 ft. 6 in. The true meteoric nature of these masses is proved by the position in which they were found, as also by the characteristic composition as a nickel-iron alloy and by the octahedral crystalline structure developed by etching.

6. *Reflections suggested by the new Theory of Matter;* by the Right Hon. ARTHUR JAMES BALFOUR, M.P. 24 pp. London and New York, 1904 (Longmans, Green & Co.).—The Presidential address of Mr. Balfour, delivered before the British Association for the Advancement of Science at Cambridge, August 17, 1904, is highly interesting and suggestive, none the less so because the author views the problems of science not as an investigator but in a sense from the outside.

7. *Ideals of Science and Faith*, edited by J. E. HAND (Longmans, Green & Co.).—The first impression that strikes the reviewer in looking over this book is that the ancient feud between science and religion seems to have disappeared. In this volume there is grouped a series of essays by writers in widely diverse fields. The ideals of faith and science are discussed in separate essays, by Sir Oliver Lodge; Professors J. Arthur Thompson, John H. Muirhead, Victor V. Branford, Bertrand Russell, Patrick Geddes; Rev. John Kelman, Rev. Roland Bayne, Rev. Philip Waggett, and Wilfred Ward. Each of these authorities approaches the subject from his own particular view-point. The volume forms delightful reading for such as are interested in broader lines of intellectual development.

8. *Long-range Weather Forecasts;* by E. B. GARRIOTT. Prepared under direction of Willis L. Moore, Chief U. S. Weather Bureau. Washington, 1904 (Weather Bureau, Bulletin No. 322).—This bulletin should be widely read by the public at large, showing as it does how little foundation exists for the general credulity in regard to the possibility of making weather predictions for the distant future. The only suggestion as to probable progress in this direction is contained in the statement, "that advances in the period and accuracy of weather forecasts depend upon a more exact study and understanding of atmospheric pressure over great areas and a determination of the influences, probably solar, that are responsible for normal and abnormal distributions of atmospheric pressure over the earth's surface."

9. *English Medicine in the Anglo-Saxon Times; The Fitz-Patrick Lectures for 1903;* by JOSEPH FRANK PAYNE, M.D. Pp. 162, with sixteen plates. Oxford, 1904 (The Clarendon Press).—This volume contains the lectures, two in number, delivered by Dr. Payne before the Royal College of Physicians of London in June, 1903, somewhat extended by the introduction of

extracts from the works discussed and by other additions. They will be read with much interest by the layman, as well as by the physician, for they give a most interesting account of the early practice of medicine and surgery in England prior to the Norman Conquest, when this practice seemed to be largely based on the use of herbs and on superstition. The accounts given, with extracts, of the Leech Book of Bald and Cid (900–950) and of the Herbarium of Apuleius (1000–1050) deserve careful attention, as well as the representation of favorite plants, often in conventionalized and attractive artistic form.

10. *Studies in General Physiology;* by JACQUES LOEB. Decennial Publications of the University of Chicago, vol. xv. Chicago, 1905. In two parts, I, pp. 1–423; Part II, pp. 425–782. Advance sheets of this work have arrived as the present number is going to press; a notice is necessarily deferred.

11. *Early Stages of Carabidae;* by GEORGE DIMMOCK and FREDERICK KNAB. Springfield, Mass., 1904.—This memoir, illustrated by four plates, forms Bulletin No. 1 of the Springfield Museum of Natural History.

## OBITUARY.

ALPHEUS SPRING PACKARD, Professor of Zoology and Geology in Brown University, died at his home in Providence, R. I., February 14, 1905, at the age of nearly sixty-six years.

Professor Packard was a son of the late Professor Alpheus Spring Packard of Bowdoin College, and was born at Brunswick, Me., February 19, 1839. He was graduated from Bowdoin in 1861, and from the Maine Medical School and the Lawrence Scientific School in 1864. At Cambridge he was one of that remarkable group of students—Hyatt, Morse, Packard, Putnam, Scudder, Shaler and Verrill—associated with the elder Agassiz in the early sixties. He served for a time in 1864–5 as Assistant Surgeon in the U. S. Army, but never became a regular practitioner of medicine, his life being devoted to his chosen work in zoology and geology. An enthusiastic field naturalist, collector, and explorer, as well as a very voluminous author who wrote on a remarkably wide range of subjects, he was specially distinguished as an entomologist. He is most widely known, and will probably be longest remembered, for his original work on insects and his several text-books on entomology and zoology. Early in his career he accepted the theory of evolution and later became an ardent neo-Lamarckian. One of his last works was, "Lamarck, the Founder of Evolution, His Life and Work." He was one of the founders of the American Naturalist, for twenty years its chief editor, and a constant contributor to its pages.

Professor Packard was a member of the National Academy of Sciences and of many European societies. Before his appointment at Brown in 1878, he was successively Librarian and Custodian of the Boston Society of Natural History, Director of the Peabody Academy of Science, State Entomologist of Mass., and a member of the U. S. Entomological Commission. S. I. S.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. XXIII.—*The Bearing of Physiography upon Suess' Theories;** by W. M. DAVIS.

**CONTENTS**:—Three conclusions reached by Suess. Observations on the Tian Shan Mountains and on the Steppes north of the Tian Shan. Peneplanation of these regions, followed by uplift of the mountains. The existing Tian Shan ranges are not demonstrably the result of tangential movement toward the south. Other examples of mountains carved in uplifted peneplains. Suess' theory of horsts; the great area of subsidence that it requires. Improbability that horsts have stood still while all the rest of the earth subsided. Horsts are probably the result of local uplifts, while all the rest of the earth remains relatively undisturbed.

THE eminent Austrian geologist, Professor Eduard Suess, has emphasized three conclusions of his researches. Uplifts are limited to mountain belts, where tangential pressure has acted to produce a resultant uplifting force; mountain ranges are of unsymmetrical structure, as a result of tangential movement, and not symmetrical as a result of axial uplift; plateau-like masses owe their altitude, not to their own uplift, but to the subsidence of the surrounding lower areas. Although displacements are elaborately discussed, it is notable, as has been pointed out by various students of Suess' works, that he gives only a minimum of attention to the processes and results of erosion, whereby so many features on the face of the earth have been given their actual expression. The present article offers some considerations on this aspect of the subject, and leads to conclusions that differ from those reached by Suess.

As a member of Professor Raphael Pumpelly's Carnegie Institution expedition to Turkestan in 1903, I had opportunity of crossing the western ranges of the Tian Shan mountain system, where the occurrence of a curious flat-topped range, the Bural-bas-tau, in the neighborhood of Son-kul (lake), attracted my attention. Its plateau-like surface was heavily snow-covered at an altitude of 12,000 or 13,000 feet or more; its northern flank was deeply gashed with deep ravines heading in glacial cirques; the rocks exposed in the cirque walls and in the sharp arêtes between the ravines seemed to be massive crystallines, but as my observations were made with a field-glass at a distance of ten or fifteen miles, this point will not be insisted upon. Yet in any case there was no indication of horizontal structure, with reference to which the even highland surface might have been determined. I have published a brief account of the range in Appalachia (x, 1904, 277–284). There is no question in my mind that the plateau-like mountain top is a displaced fragment of a peneplain, and hence that its present highland surface is the work of erosion at a comparatively moderate height above baselevel of an earlier time.

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* Revised, January, 1905, from a paper presented before the Eighth International Geographic Congress in Washington, September, 1904.

Other ranges in the Tian Shan system exhibit similar displaced or tilted blocks of a peneplain, though none of them that I saw are so remarkable in this respect as the Bural-bas-tau, whose highland combines the features of exceptional smoothness, great altitude, and unusually good preservation. The Alexander range, west of Issik-kul, seemed to be a tilted block, with a gentle slope to the south independent of structure, and an abrupt descent to the north. The western end of the Kungei Ala-tau, north of Issik-kul, was of plateau-like form. It is noteworthy that when the even highland of the western part of this range is projected eastward, it seems to rise above the serrate summits of the rest of the range. The same is true regarding the westward prolongation of the highland in the Bural-bas-tau. Both these examples therefore suggest that certain ranges of Alpine form, in which the sharp peaks now give no indication of having been carved from a flat-topped mass, may nevertheless have had precisely such an origin. It is also to be noted that in these cases the relation of the serrate peaks to the even highland is not such as to suggest that the former are recarved residuals that once rose above and more or less completely surrounded the latter. Other examples of ranges that indicate former peneplanation are described in my part of Professor Pumpelly's forthcoming report. All these ranges seemed to be isolated and dissected blocks of a broken peneplain.

Between Viernyi and Semipalatinsk (northeastern Turkestan and southern Siberia), I crossed many miles of rolling steppe of small relief and of moderate altitude above sea-level. Parts of this extended surface came nearer to the realization of a low-lying peneplain than anything that had previously come under my observation, yet even there the surface was prevailingly undulating, so that laterally swinging rivers can have had little share in its production: the only exception to this rule was in the immediate neighborhood of the Irtysh river, whose lateral swinging may have there been effective. The rocks were crystallines or disordered sedimentaries, and the gently undulating surface was evidently the result of long continued subaërial erosion. Here and there mountains rose; some of them seemed to be residual masses, as they had undulating skylines; others seemed as clearly to be isolated blocks of the peneplain, as they possessed uplands of remarkably even form. The conclusion thus grew upon me that the whole region, mountains and steppes alike, had once been greatly worn down, although it probably retained strong monadnocks here and there; and that the mountain ranges which we see to-day had been afterwards uplifted in blocks of greater or less extent; the residual eminences of the former cycle presumably form the loftiest peaks that rise above the present highlands.

This conclusion was strengthened on receiving the report of my companion, Mr. Ellsworth Huntington, who had turned southward from Issik-kul and crossed the Tian Shan to Kashgar. He found large plateau-like highlands of deformed structure and moderate relief surmounted by occasional higher eminences, monadnock-like, and deeply dissected by steep-sided valleys, and he was thus convinced that these highland areas had gained their altitude relative to sea level in comparatively recent time, after prolonged erosion: he describes the Tian Shan, where he crossed it, as "potentially but not actually mountainous." Farther eastward, however, the dominating mass of Tengri-khan is actually mountainous in a high degree: it may be provisionally regarded as a reëlevated surviving mountain group of the former cycle. On looking over the reports of other observers after my return home, several brief descriptions of the plateau-like aspect of the Tian Shan highlands were found; but the only account which interprets their meaning is by Friedrichsen, a pupil of Richthofen's, who visited the region in 1902, and who is now docent in geography at Göttingen: his articles unfortunately came to my notice only after my return from Turkestan. He recognizes the even highland which he saw southeast of Issik-kul to be a formerly lower-lying *Denudationsfläche*, now displaced and exposed to revived erosion, but thinks it may have been worn down with respect to a local baselevel in a relatively enclosed basin (Petermann's Mitteilungen, xlix, 1903, 136), and hesitates to express an opinion as to the area over which correlated peneplains once extended.

In view of these interpretations, it seems inadmissible to follow Mushketof and Suess in regarding the Tian Shan as a mountain range due to lateral pressure. Its rocks may certainly have suffered compression in some past age, for they not infrequently exhibit deformation of the kind that geologists accept with good reason as evidence of the action of tangential forces. Furthermore, the region may in some past time have risen to mountain heights as a result of such compression, for it seems reasonable to associate superficial disorder and elevation with crustal compression, whether the work of compression be superficial or deep-seated. But the time when compression deformed the rocks and when the region rose in mountain form as a result of such compression must now be long past, because the even surfaces or peneplains of the highlands and the steppes truncates the disordered structures, and thus proves that a long period of erosion—in effect, a physiographic cycle—has elapsed since the compression took place; and to this period must be added the early part of another cycle, sufficient for the dislocation, elevation and partial dissection of the peneplain and its residuals of the first cycle. The ranges that my path crossed were so largely composed of massive crystalline rocks that it is impossible for me to state what relation generally exists between the trend of the existing ranges and the strike of the deformed strata: in one small range, the trend of the crest and the strike of its steep dipping beds diverged at a strong angle; in another case, there was rough coincidence between range trend and strike of slaty cleavage; both these ranges gave good indication of having been worn down to low relief before their present altitude was gained. It is, therefore, not now possible to say what relation exists between the reliefs of the original ranges, due to compression, and the existing ranges, due to some other kind of displacement.

Whether the peneplain fragments seen in the existing ranges and the broad peneplain of the steppes were once parts of a single very extensive peneplain, or whether they represent parts of neighboring but isolated peneplains, need not now be further considered—particularly as the facts needed to settle this question are not yet in hand. It is sufficient to note that the actual attitudes of the peneplain fragments, large and small, now seen in the Tian Shan ranges are not such as to indicate the direct action of forces of horizontal compression. It is true, as above intimated, that one may suppose the dislocation of the mountain blocks to be the superficial result of a deep-seated compression; but our ignorance of the processes that go on within the earth is so profound that a speculation of this kind has no compulsory value; it certainly does not entail the classification of the existing Tian Shan system in the group of mountains due to forces of lateral compression. Hence the Tian Shan should not, in my opinion, be adduced as an example of "tangential movement directed toward the south" (Suess, Das Antilitz der Erde, i, 603; French translation, i, 619), nor should its topographic arrangement be taken to support the thesis that a certain curvature of ranges and a certain disposition of steeper slopes, noted in various mountain systems and described for the Tian Shan by Mushketof, are either the result of or the index of tangential pressure. The Tian Shan appears to be the result of displacements that have taken place in part of a very extensive degraded region: as a consequence of the displacements, large areas, that were previously below the reach of effective attack by streams, have come to be high above baselevel, so that they are exposed to the most energetic erosion. Having lived nearly through one cycle, they have now entered a second cycle of mountain sculpture; but there is no clear reason for thinking that forces of compression rather than forces of uplift have acted to renew their mountain height.

The case of the Tian Shan is less exceptional than it may appear at first sight. It is now nearly thirty years since Gilbert announced that forces of uplift, perhaps involving horizontal extension, and not forces of horizontal compression, gave the best explanation of the Basin ranges of Utah and Nevada. At a later date, various other ranges in the United States came to be regarded as uplifted masses, with more or less warping or tilting, but without recognizable compression, because their even crest lines or highlands appeared to be the result of peneplanation in an earlier cycle of erosion: the Sierra Nevada in California and the Appalachians in the Atlantic States were among the first to be thus explained; since then, the Cascade and the Coast ranges of Oregon and Washington have been similarly treated, and Gilbert has lately given an account of a lofty and dissected peneplain in the mountains of Alaska. In the meantime, similar results have been reached in Europe. The highland fjelds of Norway are now treated by Reusch and others as having been reduced to moderate relief by long-continued erosion during a lower stand of the land, and afterwards given a greater elevation: there is no indication that their present altitude has been gained by crustal compression. More recently, de Martonne has announced a similar sequence of events for the Carpathians, and Penck has done the same for the Alps. Willis' recent explorations in China led him to similar results regarding extensive mountainous tracks in that far-off country. It was indeed a matter of special interest to the physiographers who attended the International Geographic Congress last autumn to hear the independent testimony of these three observers to the effect that the ranges which they described did not owe their present altitude to forces of compression, however much their rocks may have been horizontally crushed in some earlier period of deformation; for in all three cases the mountainous areas were described as having been worn down to moderate relief after their rocks had been deformed, and their present altitude was explained as having been gained subsequently, by displacements from which the accepted characteristics of compression were absent. In none of the examples here adduced was particular attention paid by the investigators above named to the features of asymmetry and curvature of mountain tread, upon which Suess lays importance; hence that phase of his theory is not here further considered; but in so far as the present relief of the ranges mentioned is concerned, it should not, if the explanation by non-compressional displacement is correct, be ascribed to or correlated with tangential movement, however fully the internal structure of the ranges may be thus accounted for. My own observations on the Tian Shan had led to essentially the same conclusions, as already stated.

The nature of the forces by which displaced fragments of peneplains have gained their present altitude is not at once apparent, but the following considerations lead to the belief that forces of uplift may have acted in giving such ranges as the Bural-bas-tau and its fellows their actual elevation. If it be agreed that the highlands of the Tian Shan are parts of a once relatively low-lying peneplain, and that their present attitudes exclude lateral compression as a cause of their present altitude, then two contrasted explanations may be offered to account for the crustal displacement by which the rivers of the region have been excited to deep erosion of the surface that was previously safe from their attack. It may be supposed, on the one hand, that the whole region once had the altitude of the Bural-bas-tau highland and its fellows, and that since then the now lower parts of the region have subsided to the present levels; or, on the other hand, that the whole region once had an altitude similar to that of the steppes between Viernyi and Semipalatinsk—with as many and as strong monadnocks and residual ranges as further observation shall demand—and that since then the higher parts of the region have been uplifted. The first supposition is the view adopted by Suess and by a number of European geologists; the second is the view generally accepted by American geologists, as well as by some Europeans. I have not been able to devise any means of making absolute choice between the two views, but it seems to me that many reasons may be adduced for the probable correctness of the second view rather than of the first.

The theory of subsidence may be called the theory of *horsts*; *horst* being a mass of earth-crust which is limited by faults and which stands in relief with respect to its surroundings. The Harz mountains in northern Germany and the central plateau of France may be mentioned as smaller and larger examples in Europe; the plateaus of northern Arizona are examples in this country. *Graben* are the reverse of horsts, being fault-bounded areas that stand below their surroundings. The valley of the middle Rhine is a famous European example: the troughs of certain of the great African lakes, described by Gregory as "rift-valleys," are also *graben*. According to Suess' analysis of the problem, the movements which produce horsts and graben "are easily explained, in the absence of tangential movements, by a yielding of the support and by the force of gravity. Everything of this kind that one observes is only a variation on passive settling or sinking" (Das Antlitz der Erde, i, 165; French translation, i, 162). "Great plains may sink down; as soon as their support yields, they obey the action of gravity; but we know no force capable of uplifting, unequally and locally, mountainous masses situated side by side" (ibid., i, 736; i, 775). He continues, there are two facts which we cannot escape: the first is that "large areas have simply sunk down under the influence of gravity. The second is that no force is known capable of uplifting numerous great and small mountainous masses vertically and independently, between two plane surfaces, and of sustaining them in this uplifted position permanently, in spite of gravity" (ibid., i, 741; i, 782).

With all the respect that one must feel for the erudition of such a master of the geology of the whole earth as Suess has shown himself to be, the conclusions indicated in the above extracts do not seem to me to be proved. The faults by which horsts and graben are bounded truly show a differential movement, more or less nearly vertical, but the means of determining, independently of all theory, which mass went up or which mass went down are, to say the least, obscure. The observed facts of dislocation taken alone are consistent with various suppositions as to the movement of the adjoining masses: both may have moved upwards, one more than the other; both may have moved downwards, one more than the other; one may have stood still, and the other may have moved; both may have moved, one upward, the other downward. It is not satisfactory to appeal to our ignorance of available forces of uplift and support as a mean of choosing among these alternatives: the operations of the earth's interior are so little understood that we are as much in the dark about their action as they are. Nor does the accumulation of examples that may be explained by subsidence strengthen the case, unless it is shown at the same time that they cannot be explained by upheaval. The actual movement of faulted masses can be rigorously determined only by relating them to some fixed standard of comparison, and that is no easy task. It seems hopeless in the present state of our knowledge to speak of movements with respect to the earth's center; for the sea-surface and not the earth's center is our only standard of comparison. It is at best a movable standard, yet in the present problem it will fairly serve our purpose.

So far as I have been able to learn, the horsts described by Suess are not examined to discover how far the form of their surface may give indication of the altitude that they possessed with respect to sea-level before the occurrence of the faults by which they have been placed in relief: yet such an examination is well worth while. In the case of the Schiefergebirge of the middle Rhine, for example, the form of the upland is for the most part that of a well-developed peneplain, more or less warped, here and there surmounted by residual monadnocks, and now dissected by valleys. This district, therefore, stood at a moderate altitude above sea-level, before its present altitude was gained. Hence, if the present altitude were gained by the subsidence of the surrounding lower lands, we are constrained to believe that not only the surrounding lower lands, but all the oceans went down as well, and all the continents with them—the Schiefergebirge and the neighboring uplands alone standing still. The same is true of the plateau of northern Arizona, across which the Colorado has cut its precocious canyon: the plateau is a surface of denudation, and according to the most reasonable interpretation was once a lowland of small height above sea-level: if its present altitude has been passively gained by the subsidence of the surrounding lower districts, then in this case again all the oceans must also have gone down, and the rest of America and the other continents with them. Many more examples of the same kind might be mentioned, but the most impressive one that has come under my own observation is the Bural-bas-tau. It seems extravagant to suppose that all the rest of the lands and seas had to sink by some 10,000 feet in order to leave that range and its fellows in strong relief.

It is not intended, however, to imply that every horst was formed by a separate subsidence of all the rest of the world, for in so far as peneplained horsts are of the same date of production and of the same altitude, one subsidence of the rest of the world will suffice for their production; but many of the known examples of such horsts are in very different stages of dissection, and they stand at different altitudes; hence various widespread subsidences must, according to this theory, be admitted in order to account for them. It is not clear to me whether this world-wide extension of subsidence has been considered by Suess: it does not seem to be explicitly excluded in his writings; it may be that it is tacitly accepted, to be more fully treated in later volumes: he says indeed, in discussing changes of level in the Rocky mountains, "we shall have to return to questions of this kind, and I hope then to be able to show that there is need of correcting more than one widespread opinion concerning the position of sea-level in epochs anterior to ours" (ibid., i, 740; i, 782). For my own part, I know of no complete disproof of the theory of subsidence, enormous as its demands appear to be. It is in a certain sense conceivable that the Bural-bas-tau stood still, like a post in a frozen pond, while all the rest of the world went down two miles, like the sinking ice when the pond water is drawn off—this being an analogy suggested by Suess himself (ibid., i, 736; i, 774); nevertheless, in the absence of definite knowledge as to the mechanics of the earth's interior, it seems legitimate to entertain some more economical alternative hypothesis whereby the Bural-bas-tau and its fellows were locally uplifted about two miles from their former lowly estate, as a result of relatively local deep-seated movements of the earth's under mass, about which the great body of the earth knew little. How these deep-seated movements may be caused, it is impossible now to say. Two methods of search may lead to the discovery of their origin and character: one method proceeds partly from general facts as to the density, temperature and composition of the earth, and partly from general speculations as to cosmical history and the evolution of the earth; the other proceeds from special facts as to the deformations that the earth's surface has suffered, with abundant detail as to time and place. In briefer phrase, one method seeks to determine the character of the earth's internal movements from their causes; the other, from their effects. It will probably be long before either or both methods reach a solution of so recondite a problem. In the meantime, it seems advisable to take the sea-level as our standard of reference, and to speak of now high-standing isolated peneplains as locally uplifted, all the rest of the world remaining relatively undisturbed, whether the forces that produce the uplift are explained or not.

Similarly, a graben may be spoken of as a sunken area, when there is evidence that its position with respect to sea level had been lowered, as would appear to have been the case with the floor on which the Triassic beds of Massachusetts and Connecticut were deposited; but in such examples as the Rhine graben it does not seem legitimate to measure the amount of sinking from the level of the high-standing peneplains in the highlands on the east and west.

In all these cases of local change the sea surface may be provisionally regarded as fixed. A change in the level of the sea must be universal, synchronous and of equal amount (except for concomitant local changes in a land mass) along all shore lines. A universal change should be accepted only when demanded by widespread and accordant evidence, such as Suess has in so masterful a manner brought forward in the case of the world-wide Cretaceous transgression.

## ART. XXIV.—*On the Progress of the Albatross Expedition to the Eastern Pacific;* by ALEXANDER AGASSIZ.

**[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Chatham Island, Jan. 6, 1905.]**

WE left Callao for Easter Island Saturday afternoon, December 3; as far as 90° west longitude we remained in the Humboldt current, as we could readily see from the character of the temperature serials and from the amount of pelagic life we obtained from both the surface and the intermediate hauls. This current also affected the bottom fauna, which was fairly rich even as far as 800 miles from the shore while we remained within the limits of the northern current. As soon as we ran outside of this the character of the surface fauna changed; it became less and less abundant as we made our way to Easter Island, the western half of the line from Callao becoming gradually barren. This current also affected the deep-sea fauna to such an extent that towards Easter Island, at a distance of 1,200 to 1,400 miles from the South American continent, our trawl hauls were absolutely barren; the bottom of the greater part of the line was covered with manganese nodules on which were found attached a few insignificant siliceous sponges, an occasional ophiuran, and a few brachiopods or diminutive worm tubes, the same bottom continuing to Sala y Gomez and between there and Easter Island. Sala y Gomez and Easter Island are connected by a ridge on which we found 1,142 fathoms near Sala y Gomez, and 1,696 fathoms between that point and Easter Island. The ridge rises rapidly from about 2,000 fathoms, the general oceanic depth within about 100 miles, to over 1,100 fathoms within a comparatively short distance from both Sala y Gomez and Easter Island.

The southern part of our line from Easter Island to the Galapagos shows all the features characteristic of the western part of the line from Callao to Easter Island; like the latter, as far as the 12th degree of southern latitude it proved comparatively barren, the bottom consisting of manganese nodules to within about 250 miles of the Galapagos. The pelagic and intermediate fauna from Easter Island to 12° south latitude was very poor, and the serial temperatures show that we were outside and to the westward of the great Humboldt current. But near the 12th degree of southern latitude a sudden change took place; the pelagic and intermediate fauna became quite abundant again and soon fully as rich as at any time in the Humboldt current. There was also a marked change in the temperature of the water as indicated by the serials, showing that from the 12th degree of southern latitude to the Galapagos we were cutting across the western part of the Humboldt current. The great changes of temperature which took place in the layers of the water between 50 and 300 fathoms are most striking, and show what a disturbing element the great mass of cold water flowing north must be in the equatorial regions of the Panamic district to the south and to the north of the Galapagos. South of the Galapagos the western flow of the Humboldt current must be nearly 900 miles wide, and of about the same width when running parallel to the South American coast.

The range of temperatures between 30 fathoms and 150 fathoms is at some points as great as 21°. Such extremes cannot fail to affect the distribution of the pelagic fauna, and may account for the mass of dead material often collected in the intermediate tows at depths of less than 300 fathoms, when the range becomes as great as 28°. Such a range of temperature is far greater than that of the isocrymic lines which separate coast faunal divisions. The bottom fauna, as we entered the Humboldt current going north, gradually became richer in spite of its being covered with manganese nodules.

The two lines centering at Easter Island developed the Albatross Plateau indicated on the Challenger bathymetrical charts, on the strength of a few soundings reaching from Callao in a northwesterly direction and of a couple of soundings on the 20th degree of latitude. The Albatross Plateau is marked as a broad ridge separating the Buchan Basin from the deep basin to the westward, of which Grey Deep and the Moser Basin are the most noted areas.

Our line from Easter Island to the Galapagos showed a wonderfully level ridge, varying in depth only from 2,020 to 2,265 fathoms in a distance of nearly 2,000 miles. The soundings we made to the eastward from the Galapagos to the South American coast, and to the westward of Callao, as well as on the line from Callao to Easter Island, all indicate a gradual deepening to the eastward to form what the Challenger has called the Buchan Basin with the greatest depths of 2,400 to over 2,700 fathoms and passing at several points near the coast to Milne-Edwards Deep, Haeckel Deep, Krümmel Deep, and Richards Deep, some of them with a depth of over 4,000 fathoms. According to the Challenger soundings the Juan Fernandez Plateau connects with the Albatross Plateau and forms the southern limit separating Buchan Basin from the Barker Basin to the south of the Juan Fernandez Plateau.

At Easter Island we found our collier awaiting our arrival. We moved from Cook Bay to La Pérouse Bay to coal, as there was less swell there than in Cook Bay, where we could scarcely have gone alongside for this purpose.

Considerable shore collecting was done at Easter Island. We must have brought together at least 30 species of plants. The flora of Easter Island is very poor. There are no trees nor native bushes—not even the bushes which characterize the shore tracts of the most isolated coral reefs of the Pacific are found there; and yet some of the equatorial counter-currents must occasionally bring some flotsam to its shores. We collected a number of shore fishes and made a small collection of the littoral fauna. The fishes have a decided Pacific look, and the few species of sea-urchins we came across are species having a wide distribution in the Pacific.

While coaling, we spent some time examining the prehistoric monuments which line the shores of Easter Island. During our stay at La Pérouse Bay we visited the platforms studding the coast of the bay, and made an excursion to the crater of Rana Roraka, where are situated the great quarries from which are cut the colossal images now scattered all over the island, many of which have fallen near the platforms upon which they were erected. Near Rana Roraka, at Tongariki, is the largest platform on the island, about 450 feet in length, to the rear of which are 15 huge images which have fallen from the pedestals upon which they once stood. The plain in the rear of the platform is crowded with stone houses, most of which are in ruins.

On our return to our anchorage at Cook Bay, we examined the platforms within easy reach of the settlement, and also the crater of Rana Kao, on the north rim of which, at Orongo, are a number of the stone houses built by the people who quarried the great stone images. At Orongo are also found sculptured rocks, but neither the sculptures nor the images show any artistic qualities, though the fitting of some of the cyclopean stones used in building the faces of the platforms indicates excellent and careful workmanship. To Mr. C. Cooper, manager of the Easter Island Company, we are indebted for assistance while visiting the points of interest of the island. He was indefatigable in his exertions in our behalf.

We took a number of photographs during our stay, illustrating not only the prehistoric remains, but giving also an idea of the desolate aspect of Easter Island during the dry season.

We arrived at Wreck Bay, Chatham Island, Galapagos, on the 3d of January, where we found a schooner with a supply of coal. As soon as the ship has been overhauled and coaled we shall start for Manga Reva, where we ought to arrive the last days of January. We reached Chatham Island towards the end of the dry season. Everything is dried up; the vegetation seems dead with the exception of a few small wild cotton plants, weeds, cactus, and an occasional mimosa; and the great barren slopes present fully as uninviting an aspect as when Darwin described them. When the Albatross visited the Galapagos in March, 1891, everything was green, presenting a very marked contrast to its present desolate appearance.

# ART. XXV.—*Replacement of Quartz by Pyrite and Corrosion of Quartz Pebbles;* by C. H. SMYTH, JR. (With Plate II.)

## I. *Replacement of Quartz by Pyrite.*

THE lowest beds of the Oneida conglomerate, in Central New York, are characterized by the presence of considerable pyrite, serving as a cement to bind together the quartz grains and pebbles of which the rock is mainly composed. The relations between the two minerals are worthy of note.

The quartz is, of course, clastic, while the pyrite has been deposited from solution, and would naturally be expected simply to fill the interstices between the more or less perfectly rounded grains of the former mineral, as is the case with the secondary quartz cement of the upper beds of conglomerate.

The pyrite, however, behaves quite differently. Instead of being molded upon the quartz grains and taking its shape from them, the reverse relation holds good, and the form of the pyrite is deeply impressed upon the quartz grains, giving them angular, jagged and pitted contours, totally unlike their original clastic forms. That these contours are secondary and conditioned by the pyrite, admits of no doubt; for not only is the shape of the grains wholly incompatible with water transportation, but, when sections are examined in detail, it is evident that the outlines of the quartz grains are commonly determined by crystal faces of the pyrite, the latter mineral occurring with its own forms, pyritohedron and cube, to which the older quartz has been forced to accommodate itself. In other words, the surfaces of the quartz are such as would have resulted had it been deposited from solution upon the already crystallized pyrite, which is just the reverse of the actual relation. The pyrite seems to have crystallized as readily as though filling open spaces or pushing aside some soft medium, like clay, instead of forcing its way into so refractory a substance as quartz; and, in consequence, the quartz grains are bounded, not by their normal, water-worn surfaces, but by variously oriented minute planes, conforming to the crystal faces of pyrite. Between such grains and those showing their original contour there is a complete gradation, and some of the latter are surrounded by pyrite. But this is decidedly exceptional, the pyrite nearly always eating its way to a greater or less distance into the quartz, while in the absence of pyrite the quartz retains its original form.

Some idea of these various features may be gathered from the accompanying photomicrographs (Plate II). Although affording a very unsatisfactory substitute for actual sections under the microscope, they suffice to show that the relation between the two minerals is quite different from that ordinarily subsisting between clastic quartz grains and their cement, and can be explained only as resulting from the simultaneous solution of quartz and deposition of pyrite, or, in other words, the metasomatic replacement of quartz by pyrite.

The amount of replacement varies considerably, even within the limits of an ordinary thin section, and sometimes a grain of quartz is considerably replaced on one side, showing the jagged contour impressed by the pyrite, while the other side retains the clearly defined original outline. Figures 1, 5 and 6 (Plate II) show cases of this kind, where the replacement is in early stages and the grains retain their original outlines to some extent, although the pyrite has eaten into them considerably. In figures 2 and 4, on the other hand, few traces of the original margins of the grains are left.

Thus far, in spite of the variation in the amount of replacement, no section has been seen which contains pyrite and does not show replacement. Even where there are but a few scattered crystals of pyrite, they have eaten into the adjacent quartz just as in parts of the rock that are strongly pyritiferous (fig. 1). Sometimes such isolated crystals, and even larger masses of pyrite occur entirely within quartz grains, having, doubtless, been deposited from solutions entering cracks. It is evident, however, that, as a rule, the replacement started at the surfaces of the grains.

This is a matter of interest in its bearing upon the history of the replacement, as it shows plainly that the solutions effecting the change circulated through the beds of sand and gravel before they were cemented. For, had these beds been indurated, as the upper beds are now, by secondary quartz, filling the interstices between the grains, any replacement that might have followed would have been controlled by secondary surfaces, resulting from fractures subsequent to cementation, and would show no such dependence upon the original surfaces of the quartz grains.

Such openings as escaped complete filling by pyrite were subsequently closed by secondary quartz. It is evident that when this happened the quartz would take the form of the pyrite, and thus give a texture identical in appearance with that described above. This relation is shown in figures 3, 5 and 6, and may be seen frequently in the sections, but it is always a minor feature; and while, in photographs with low powers, it might be confused with replacement, when seen under the microscope, the results of the two processes are easily distinguished, as they are in figures 5 and 6. There might be some doubt in the case of very small grains, but with reference to the general relation of quartz and pyrite in the rock, secondary quartz is an entirely negligible factor.

As to the relative amounts of interstitial filling and of replacement, the evidence is quite clear. In the non-pyritiferous rock, the quartz grains are very closely packed and the interstitial filling correspondingly slight, but in the pyritiferous beds the quantity of pyrite between the grains is often considerable. The amount of replacement is greater or less according as the original interstitial space was large or small. While sometimes well-rounded grains are widely separated by pyrite, much the commoner case is the occurrence of jagged contours, and when parts of the original surfaces remain, it is evident that their complete restoration would largely take up the space now filled by pyrite (figs. 5 and 6).

This is repeated so often that it is deemed excellent evidence for believing that the original sand was closely packed, like that of the overlying beds, with small interstitial cavities, and that the considerable space now occupied by pyrite is due chiefly to replacement. According to this view, figures 2, 3 and 4 represent later stages in a process whose earlier stages are represented by figures 1 and 5.

If the space now filled by pyrite were regarded as original, it might be concluded, as there is no reason for assuming the former presence of any other cement, that the sand and pyrite were deposited simultaneously, the pyrite coating the grains and thus keeping them from being closely packed. Primary deposition of pyrite in sediments is common, an instance described by Reusch* being of particular interest in this connection; and this explanation is favored by the apparently fixed stratigraphic position of the pyrite, and the fact that it was deposited before the secondary quartz. But if the foregoing interpretation of the texture of the rock is correct, a later introduction of the pyrite is indicated; although, so far as the evidence goes, it may have followed closely upon the deposition of the sand and gravel, while they were still exposed upon the sea bottom. This latter view, which is but a slight modification of the preceding, would account equally well for the position of the pyrite and for its deposition before the secondary quartz.

While it is a general rule that the primary pyrite of sediments is deposited in the presence of abundant organic matter, which is lacking in the conglomerate, the underlying Lorraine formation would be a possible source of hydrogen sulphide and other reducing agents.

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* Neues Jahrbuch f. Mineralogie, etc., 1879, p. 255.

Thus, so far as the pyrite itself is concerned, there is reason for thinking that it was deposited in the gravel and sand lying uncovered on the sea bottom. But, on the other hand, it is difficult to believe that, had the pyrite been so deposited, there would have been any replacement of quartz. Such metasomatic processes usually take place after rocks are deeply buried, and subjected to the action of underground waters; and while, in the case of a readily soluble mineral, such as calcite, sedimentation and replacement are often practically simultaneous, with our present limited knowledge of the chemical reactions on the sea bottom, it seems unlikely, in spite of the evidence given later as to the solubility of quartz under surface conditions, that this would be true of quartz. Thus, it appears probable that the replacement of quartz by pyrite was effected by ground waters, rather than by chemical reactions coincident with, or directly following, the deposition of the sand and gravel. But as this conclusion is based upon general considerations rather than upon direct and positive evidence, it may be modified by future investigation.

As to the bearing of the stratigraphic position of the pyrite upon the above conclusions, it should be said that, owing to the unsatisfactory exposures of the formation, there is much to be learned with reference to the precise distribution of the pyrite, and it is certain that the higher beds often contain enough of the mineral to weather yellow, brown and black. It seems, therefore, unwise to lay great stress upon the stratigraphic position until it is more accurately determined.

However, even if the pyrite is largely confined to a definite horizon, at the bottom of the conglomerate, it is possible to reconcile the fact with the above conclusion as to its secondary origin. Before cementation, the conglomerate must have been a permeable formation, permitting a free circulation of water. Immediately beneath it, on the other hand, the fine-grained Lorraine formation would be relatively impervious, and thus, along the contact, or in the bottom beds of the conglomerate, the conditions would be favorable for deposition. These beds might be quite uniformly impregnated with such a mineral as pyrite, which, in consequence, would have a definite stratigraphic position, in spite of its secondary origin.

With so much that is uncertain, it is not worth while to make any attempt to explain in detail the chemistry of the deposition of pyrite and replacement of quartz, but it is natural to suppose that hydrogen sulphide and iron and alkaline carbonates were active agents in the process. These compounds are sufficiently common in ground-waters to warrant the assumption of their former presence where effects are observed of which they would be a probable cause, although there are

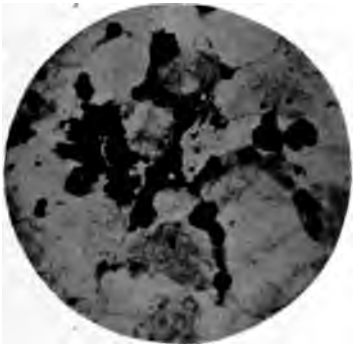

Fig. 1, × 26 diam.

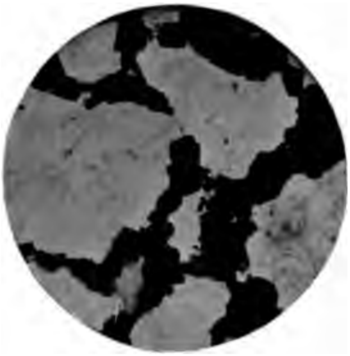

Fig. 2, × 26 diam.

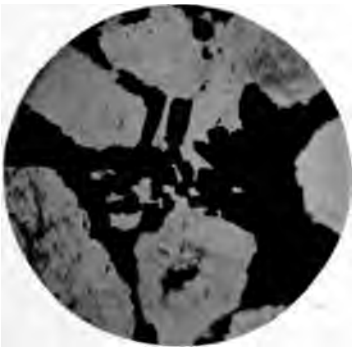

Fig. 3, × 26 diam.

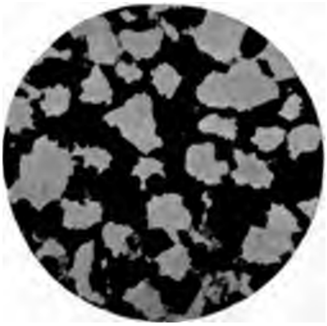

Fig. 4, × 23 diam.

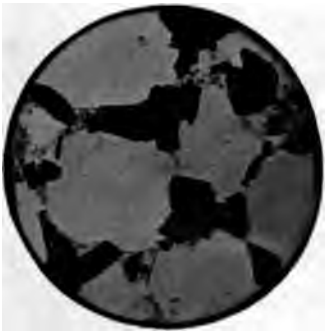

Fig. 5, × 67 diam.

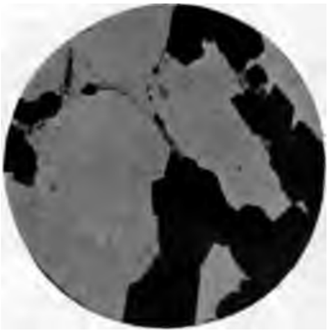

Fig. 6, × 67 diam.

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Fig. 1. × 25 diam.

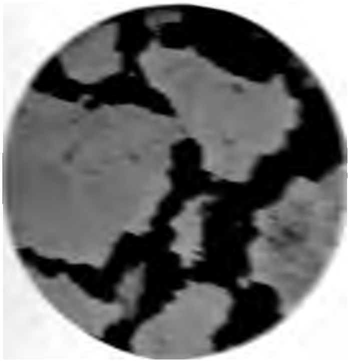

Fig. 2. × 24 diam.

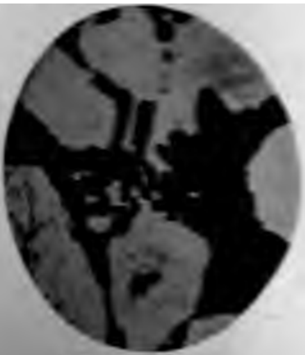

Fig. 3. × 25 diam.

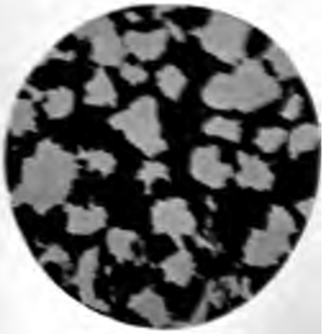

Fig. 4. × 23 diam.

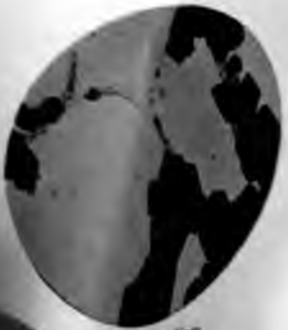

Fig. 6. × 67 diam.

difficulties as regards concentration. In the present case, while there is no obvious source for any unusual quantity of alkaline carbonates, a sufficient supply might, perhaps, be furnished by overlying shales, while the Lorraine formation might be a source of hydrogen sulphide. Iron may have been original in the conglomerate, or derived from overlying rocks. In this connection, Doelter's[*] production of artificial pyrite by the action of hydrogen sulphide and sodium sulphide on iron carbonate is very suggestive, and may represent some approximation to the conditions involved in the case under consideration.[†]

If this is true, it is evident that the replacement of quartz by pyrite is caused by common, rather than peculiar, agents, and therefore might be expected to occur with some frequency. As a matter of fact, judging from the literature of ore deposits, it is by no means rare. Lindgren[‡] in particular has described several instances within very recent years.

But in all the cases that the writer has thus far found mentioned, the process is connected with some type of mineral vein formation, where, with the hot alkaline solutions and mineralizers, and resultant powerful chemical action, it is not surprising to find even so resistant a mineral as quartz yielding to the agents of alteration. In some of these cases it is, as in the present instance, the quartz of sedimentary rocks that is replaced, but always under the conditions involved in the filling of mineral veins.

These conditions are so unlike those controlling the deposition and subsequent existence of the Oneida conglomerate that the occurrence of pyrite replacing quartz in veins would hardly suggest the probability of the same thing taking place in the conglomerate, and explanations of the former process would, doubtless, require modification before being applied to the latter.

The reagents suggested above are similar to those filling veins, but in the case of the conglomerate their action would, probably, be less intense, owing to lower temperatures and pressures, greater dilution, and the absence of some of the more powerful reagents. Compensation might be afforded by the ready permeability of the formation and the large surface of quartz exposed to attack, while, of course, the time factor would be most important in determining the amount of replacement.

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[*] Allgemeine Chemische Mineralogie, p. 148.

[†] See a theoretical discussion of the chemistry of pyrite-quartz replacement by C. S. Palmer, Eng. and Min. Jour., lxxix, p. 169.

[‡] Metasomatic Processes in Fissure Veins, Trans. Am. Inst. Min. Eng., xxx, p. 615, et seq.

Gold and Silver Veins in Idaho, 20th Ann. Report, U. S. Geol. Survey, iii, p. 219 et seq.

Geological Reconnaissance across the Bitterroot Range, etc. U. S. Geol. Survey, Professional Paper No. 27, pp. 109–110.

How frequently all the conditions necessary for the replacement of quartz by pyrite are fulfilled in formations similar to the Oneida conglomerate, it is at present impossible to say. Judging from the literature, the matter has never been investigated, which doubtless explains the fact that, so far as the writer can learn, no case similar to the present one has been described.

Whatever sheds light upon the geological relations of so important a mineral as quartz is worth recording, but it is evident that this case of the replacement of quartz by pyrite is of particular significance in its bearing upon ore deposits. In the present instance, the total amount of replacement is comparatively small, but there seems to be no reason why, under more favorable conditions, there should not be a more extensive, or even complete, replacement of quartz by pyrite, and, perhaps, by other sulphides. Although this may be going too far, it is, at least, evident that the phenomena described suggest interesting possibilities.

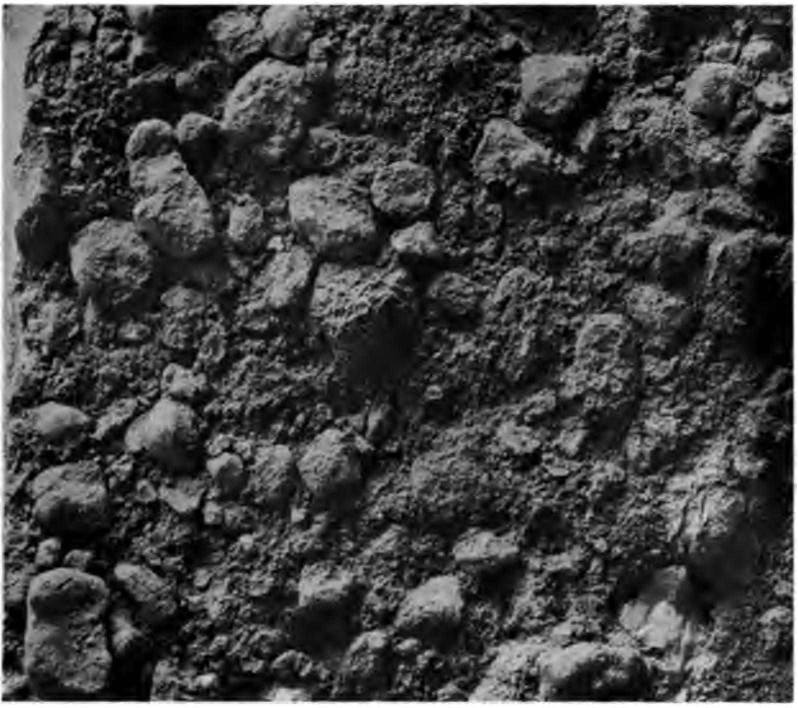
## II. *Corrosion of Quartz Pebbles.*

While the replacement of the quartz is clearly a process which was accomplished early in the history of the conglomerate, the same mineral occasionally shows evidence of another change, going on under very different conditions at the present time. Several specimens have been found with projecting pebbles of quartz deeply corroded in a manner indicating the action of some solvent, working, not throughout the mass of the rock, but upon surfaces of bedding planes, or, rarely, of joints and boulders—in other words, where there is exposure to weathering conditions.

The pebbles show most irregular surfaces, often pitted, with sharp jagged projections, and in extreme cases, appear to have lost a considerable fraction of the original mass. As a rule, solution has been most rapid on the tops of the pebbles, and as the cement and sand work out beneath, there is also rapid solution here, the result being the reduction of pebbles to thin plates, with very jagged edges and rough surfaces. Such a marked effect is, however, exceptional, the pebbles more commonly showing a less pronounced change of form, but having the characteristic etched surfaces. The accompanying illustration from a photograph (fig. 1), showing a portion of the surface of a typical specimen (natural size), gives a fairly clear representation of corroded pebbles. While the sand grains are similarly affected, the phenomena are, naturally, much less easily observed.

Unlike the replacement by pyrite, this corrosion of the quartz seems to be a rather exceptional feature of the rock, as but few good examples have been found.

The character of the corroded pebbles is essentially the same as that described by Hayes* and by Fuller,† but in both of these latter cases the pebbles appear to have suffered greater loss, while there is a stronger tendency towards a rapid solution of the center of the pebble, leaving the margin as a projecting rim. This form is seldom even approximated in the Oneida specimens, but the resemblance to wind-facetted pebbles, noted by Hayes, is sometimes quite pronounced.



Hayes explains the corrosion as due to the action of the azo-humic acids of decaying organic matter, combined with potash derived from forest fires, and regards the process as taking place at the surface.

Fuller concludes that the quartz is dissolved by organic acids supplied by plants buried in the rock when it was deposited, and holds that the process has taken place at moderate depth beneath the surface.

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* Bull. Geol. Soc. Am., viii, pp. 213–226.

† Jour. Geol., x, pp. 815–821.

Long ago, Newberry* regarded the impressions of plant stems upon the quartz pebbles of conglomerate as due to organic acids, and, as quoted by Bolton,† explained in the same way the corrosion of quartz pebbles occurring in carbonaceous clay.

As the present instances of corrosion show no connection with unusual supplies of decomposing organic matter and alkalies, at the surface; and as the conglomerate contains little, if any, original organic matter, none of these explanations seems applicable; but, unfortunately, no satisfactory substitute is forthcoming.

As already stated, the corrosion appears to be a superficial process—a peculiar phase of weathering. To this may be added the striking fact that, thus far, corroded pebbles have been found only in the pyritiferous beds, though carefully sought for in the overlying pure quartz conglomerate.

Thus, corrosion seems to be dependent upon two conditions, —presence of pyrite and weathering,—which suggests the conclusion that the products of the weathering of pyrite act as solvents of quartz. But, so far as the writer is aware, such a conclusion finds no support in the results of laboratory study; and an explanation of the phenomena must await further investigation.

It might be suggested that the corrosion is merely apparent, not real, resulting from the weathering out of pyrite from partly replaced quartz, thus leaving, as would evidently be the case, a rough pitted surface. This simple explanation is not, however, in harmony with the facts. The replacement though greatly modifying the shape of small sand grains, perhaps even completely destroying them in some cases, does not go deep enough to materially change the shape of the larger pebbles, upon which corrosion is conspicuous. So, while mere weathering out of pyrite would give a rough surface, it would not yield the deeply corroded pebbles. Furthermore, a surface left by the removal of pyrite would be marked by depressions corresponding in shape with the pyrite, and, thus, often bounded by small plane faces, which is distinctly not the case with the corroded pebbles.

The rough surface left by the removal of pyrite would, of course, favor solution of the quartz by any agent present, and to this extent, surely, replacement is a factor in the subsequent corrosion.

The Oneida conglomerate, then, presents two types of solution of quartz, one accompanied by simultaneous replacement by pyrite, and thus metasomatic, the other purely destructive in its nature, and in harmony with the general tendency of weathering. While neither of these processes is of great moment in the history of the formation as a whole, they are interesting in that, as they seem to represent no very unusual conditions, they suggest the possibility that quartz, though unquestionably an exceedingly resistant mineral, may yield rather more readily to the attack of natural solvents than has generally been supposed.

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* Geol. of Ohio, vol. ii, pt. I, p. 111.

† Ann. N. Y. Acad. Sci., i, 1877, pp. 35-36.

Hamilton College, Clinton, N. Y.

### DESCRIPTION OF PLATE II.

FIGURE 1.—Early stage of replacement, with crystals and irregular masses of pyrite growing between, and into, the quartz grains. Magnified 26 diameters.

FIGURE 2.—Original margins of quartz grains almost entirely removed, giving jagged contours determined by the forms of pyrite. Magnified 26 diameters.

FIGURE 3.—Pyrite with unusually irregular forms. Some secondary quartz in upper half of section. Magnified 26 diameters.

FIGURE 4.—A typical example of replacement in a fine-grained specimen. Nearly all the quartz grains are affected, and show the characteristic contours resulting. It is quite possible that some small grains have entirely disappeared. Magnified 23 diameters.

FIGURE 5.—Pyrite filling interstitial spaces, and projecting slightly into quartz grains, whose original margins are partly preserved. Some secondary quartz. Magnified 67 diameters.

FIGURE 6.—Shows very clearly the contrast between original and secondary contours of quartz grains, together with the dependance of the latter upon the forms of pyrite. Some secondary quartz. Magnified 67 diameters.

## ART. XXVI.—*Occurrence and Distribution of Celestite-Bearing Rocks*;* by EDWARD H. KRAUS.

IN July, 1904,† I announced the fact that the mineral celestite occurs quite extensively in a disseminated condition in the dolomitic limestones and shales in the upper portion of the Salina epoch. The celestite-bearing rocks studied at that time were confined to localities in Central New York, especially those near Syracuse. However, in describing the various occurrences, the following statement was made: "I do not doubt, whatever, but that its (celestite) occurrence in the disseminated condition, as shown by the accompanying figures, is just as extensive in the limestones of the Salina elsewhere, as in the vicinity of Syracuse."‡

During the past summer, the Island of Put-in-Bay in Lake Erie was visited. This island has become well known for its interesting caves, among which is the celestite cave, popularly known as "Crystal" or "Strontium" cave. The rocks of the island have been assigned to the Lower Helderberg epoch. Wherever they are exposed along the lake shore they present a more or less porous appearance. There are a goodly number of exposures in various places on the island away from the shore, and even in such places many of the rocks have a structure which is so characteristic of the leached celestite-bearing rocks of Central New York. Numerous specimens were found lying on the surface, which possess cavities with a distinct orthorhombic outline. A very careful search failed to reveal celestite in the interior of such rocks, but the outline of the cavities leaves no doubt, whatever, as to the mineral which had previously occupied them. There is a very striking similarity between these rocks from Put-in-Bay and those from various localities near Syracuse, N. Y. In some instances it would be difficult to tell which specimens were from either place, were it not for the fact that those from Put-in-Bay are for the most part a little lighter in color.

The dissemination of the celestite in the rocks near the surface in the Put-in-Bay region was principally, so far as I have been able to ascertain, in the form of small but well-defined crystals. Celestite has been known to occur for many years at this locality, and also on some of the other islands in the southwestern portion of Lake Erie. Nearly all text-books on mineralogy mention these islands as important localities for the mineral. The celestite, however, which has been studied up to the present time has, in so far as my knowledge goes, all been of secondary origin, in that it has always been found in the cracks, crevices, or cavities in the rocks.

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* Read in part before the Philadelphia meeting of the Geological Society of America, December 30, 1904.

† This Journal (4), xviii, 30–39, 1904.

‡ Ibid. (4), xviii, 38, 1904.

The discovery of the "Strontium" or "Crystal" cave in 1897 showed conclusively that there must have existed somewhere on the island a very large amount of celestite. This cave is perhaps 25 to 30 feet in its extreme dimensions. The form is somewhat irregular and the interior is lined on all sides with well-developed crystals of celestite, some of which are eighteen inches in length. In opening this cave to the public it was necessary to remove some of these crystals in order that suitable passageways might be made. The owner, Mr. Gustave Heinemann, estimates that in so doing no less than 150 tons of celestite were removed. This, however, represents but a small portion of what still remains.

G. F. Wright,* in describing this cave, speaks of it as an immense geode. There is no doubt, whatever, of the secondary origin of the celestite. An examination of the rocks immediately overlying the cave shows that they are of a more or less porous nature.

At the time of my visit to the island in August, 1904, several wells had just been drilled—one on the farm of Louis Schiele on the southeast shore of the lake, and the other at the hotel of August Markley on the road extending southward from the main dock. This last well is not over a quarter of a mile from the "Strontium" cave. Many cores were obtained from these wells. These cores show that the rocks near the surface are very porous. In many instances the cavities are well preserved and reveal the celestite outline. The rocks near the surface show small cavities, but as we go deeper the cavities become much larger, some over an inch in diameter, and the rocks are crossed by numerous cracks. It is in these larger cavities and cracks that excellent crystallizations of celestite are found. These lower cavities, however, do not possess a definite outline, but are more or less irregular. The crystals do not in all cases completely fill the cavity, and in no case does the cavity conform to the celestite outline, as is the case when the mineral occurs disseminated. Figure 1 shows a core from the Schiele well. This core is from the strata near the surface, and shows clearly the porous condition of the rocks. It is not possible for me to give exact figures as to the depth at which this core was obtained, nor can I state how far below the surface celestite is first encountered filling the larger cavities and cracks, for no detailed record of either this or the

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* Science, viii, 502, 1898.

Markley well was kept by the driller, Mr. W. T. Hills. This much, however, can be stated, that the cores from the upper strata show that celestite was present in a disseminated condition, and thus the observations on the surface rocks, which were referred to above, are confirmed. Since this is the case, it can be readily seen that these leached rocks are no doubt the source of the large amounts of celestite which are to be found in some of the lower strata. In this way the very large deposit of celestite, which is to be found in the "Crystal" cave, may be readily explained.

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In the paper* already referred to, it was shown that the porous character of celestite-bearing rocks is due to the solution of the celestite, brought about by the action of the circulating waters, and figures are given showing that if sodium chloride or the chloride of calcium or magnesium be present in the water, the same becomes an excellent solvent for celestite.† Virick‡ says, that one part of celestite is soluble in but 457 parts of water containing 15 per cent. of sodium chloride in solution. Hopper casts were found in several places on the island, so that, without a doubt, conditions for obtaining a suitable solvent for celestite are also present in the Put-in-Bay region as well as in Central New York.

There is, however, another point concerning the solubility of celestite which is worthy of consideration. It is sometimes supposed that, because celestite resists to a very large extent the action of the common acids, it is insoluble or only very slightly soluble in water. A few figures will suffice to show that such a view is erroneous. According to Fresenius,§ one part of the celestite is soluble in 6,895 parts of cold water. F. Kohlrausch and F. Rose‖ found the solubility of celestite to be one part in 10,101 parts of water at 15° C. Hollemann¶ also obtained figures almost identical with these, namely, one part in 10,070 parts of water at 16·1°C. But, inasmuch as the celestite usually occurs disseminated in limestones, let us compare with the above figures concerning the solubility of celestite, some showing the solubility of calcite. Perhaps the most reliable are those of F. Kohlrausch and F. Rose,* namely, that one part of calcite is soluble in 76,924 parts of water at 15° C.

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* This Journal (4), xviii, 36, 1904.

† Since the publication of said paper expressing the belief that the Vermicular limestones of Central New York owe their origin to the removal of celestite—once disseminated throughout them—by percolating waters containing sodium chloride in solution, I have found that in 1869 Bauermann and Foster (Phil. Mag., 38, 1862) had expressed similar ideas concerning the solution of celestite in nature.

‡ Chemisches Centralblatt, 1862, 402; Comey, Dictionary of Chemical Solubilities, 1895, 455.

§ Ann. der Chemie, Bd. lix, 122. ‖ Zeitschr. für physikal. Chemie, xii, 162–166, 1893.

¶ Zeit. für Physikal. Chemie, xii, 125–139, 1893.

A comparison of these figures for the solubility of calcite with the highest for celestite, which are by the same authorities — Kohlrausch and Rose — shows that celestite is more than seven (7) times as soluble as the limestone rock in which it usually occurs. But in this comparison we have considered the limestone to consist of pure calcium carbonate, which is not the case. They are more or less dolomitic and also contain some silica, thus their solubility would be even less than that indicated for calcite. Of course, waters circulating in nature are never pure, but contain oftentimes, among other compounds in solution, varying amounts of carbon dioxide, which increases to a very considerable extent the solubility of the carbonate rocks. The porous character of these rocks, however, shows conclusively that there is not enough of the carbon dioxide in the percolating waters to cause the limestones to dissolve more readily than the celestite. We can, also, readily see that in order to account for the comparatively easy solubility of celestite over the carbonate rocks, it is not at all necessary to assume the presence of extraordinary amounts of sodium, calcium, or magnesium chlorides in the circulating water.

Thus, by the continued action of water, the celestite disseminated in the strata near the surface, would pass into solution, and as this descends the mineral may, under certain conditions, be again deposited. In this way, the occurrence of celestite in the cracks and cavities is to be explained. The same explanation also applies to the "Crystal" cave. This cave, the ceiling of which is perhaps 15 to 20 feet below the surface, is a large cavity. Into this large cavity or cave, water containing celestite in solution, which was obtained from the overlying strata, flowed, and from it the large crystals crystallized. These large and well-developed crystals indicate that crystallization took place without any serious disturbance or interruption, there being a continual addition of material, i. e., as fast as the celestite was deposited more was brought in by the descending water. Such occurrences of celestite—in the cracks and cavities—are of course of secondary origin.

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* Zeit. für. physikal. Chemie, xii, 162–166, 1893.

Another interesting locality, where celestite-bearing rocks may be studied to advantage, is the Woolmith quarry, located in Exeter township, midway between Maybee and Scofield, Monroe County, Michigan. The geology of this county has been thoroughly studied by Sherzer and a detailed account of the various strata occurring at the Woolmith quarry is given in his excellent "Geological Report of Monroe County."* Sherzer distinguishes nine different beds at this locality and assigns them to the Monroe series, which is, doubtless, the equivalent of the Salina in New York. For this discussion, however, it is important that the strata near the surface contain a very large amount of celestite disseminated throughout them. In several specimens, taken from what Sherzer calls bed A, crystals of celestite can be easily recognized. That some substance possessing a high specific gravity is present is evidenced by the fact that several determinations of the specific gravity of one of the specimens gave figures as high as 3·45. These rocks are dolomitic and therefore ought to possess a specific gravity of about 2·85 to 2·90. Where they have been protected from the action of water, these rocks are compact, but where they have been exposed for only a short time they assume the porous structure characteristic of celestite-bearing rocks. As in the other localities, referred to above, many of the rocks possess cavities sufficiently well preserved so that the orthorhombic outline may be readily recognized.

In the lower beds many cavities of an irregular nature, varying from a few inches up to a foot or two, are found. In these cavities beautiful crystallizations of celestite are to be noted. In some instances, the crystals are from four to six inches in length. Associated with the celestite there oftentimes occurs a considerable quantity of native sulphur and also, now and then, small amounts of calcite. The celestite is, however, by far the predominant mineral.

At this locality the changes, which are now actually taking place, may be followed very easily and furnish the best of evidence in proof of the solution of celestite in the strata near the surface and deposition in the lower and cavernous beds. The well-developed crystals of celestite, — in some cases four to six inches in length — which are found in these larger cavities in the lower strata, are therefore the result of transportation by means of solution from the higher to the lower layers of rock, and not, as Sherzer† suggests. due to the interaction in these cavities of a solution of gypsum with another containing a soluble salt of strontium. That the celestite has actually gone into solution is shown, first, by the peculiar porous structure of the leached rocks, and secondly, that many celestite veins can be found crossing the various strata, usually in a vertical direction.

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* Part I, volume viii of the Geological Survey of Michigan, 1900.

† Geological Report of Monroe County, 1900, 208.

As already said, many of these leached rocks possess cavities with outlines well enough preserved so that no doubt exists as to what the mineral was which originally occupied them. The best of such cavities, which have been studied thus far, are usually quite small. In many instances cavities are encountered which cannot be readily recognized as having been caused by the solution of celestite. Some of these appear as though the point of a knife had been thrust into the rock material while in the process of hardening, and on this account the term "gashed" dolomites has been used by Lane, Sherzer and others.

Sherzer* refers especially to such an occurrence at the Ida quarries, likewise in Monroe County, but adds that such phenomena can be seen throughout the whole Monroe series. In fact, this peculiar structure has been observed in many places in Michigan. Winchell in his report of 1860 calls it an "acicular" structure. He thought that gypsum was the original occupant of the cavities. Later on, Rominger also used the term acicular but made no definite statement as to what mineral had occupied the cavities. Lane,† however, mentioned calcite as possibly having been the original occupant. One of the difficulties in recognizing the original occupant of such "gashed" cavities has been due to the fact that the orthorhombic outline is not always definitely preserved. Sherzer aptly describes them as follows: "The rock looks as though, when it was only very slightly plastic, it had been jabbed in every direction with a thin-bladed, doubled-edged knife point. The gashes are always open, intersect one another irregularly and vary greatly in size, some being two-thirds of an inch long, while others can scarcely be seen without the magnifier. The cross-section of each gash shows that it is thickest at the center and that it slopes gradually and symmetrically to a very thin edge." Such an outline can be readily referred to celestite, when we bear in mind that crystals of this mineral are often found which have a tabular habitus, that is, the basal pinacoid is predominant. Cross-sections through such tabular crystals would conform very closely indeed to Sherzer's description above of the so-called "gashes."

Another reason why the original occupant of these cavities evaded detection lies in the fact, that celestite had not up to the present time ever been noted as occurring in these rocks in a disseminated condition, that is, in a condition of primary origin. Therefore, with these facts before us, first, that celes-

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*** Geological Report of Monroe County, 1900, 85.**
**† Ibid., foot-note, p. 86.**

tite does occur very extensively in the dolomitic limestones of the Monroe series in a disseminated condition, and secondly, that when the mineral is thus disseminated it is usually in the form of well-defined crystals of either a prismatic or tabular habitus, and thirdly, that since celestite is, as previously shown, quite readily removed by the continued action of water, *we have every reason to believe that the phenomenon referred to as "gashing" or "acicular structure" has been produced by the mineral celestite.*

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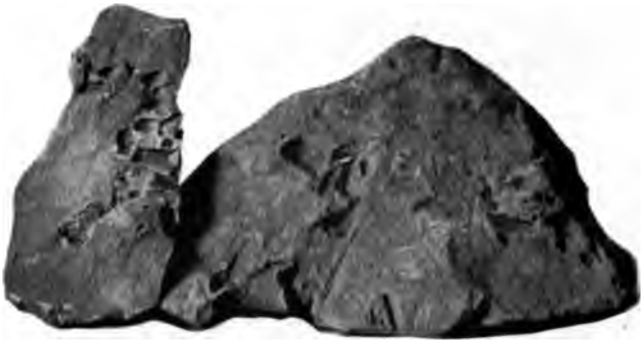

As previously noted, the celestite in these three localities occurs in a so-called disseminated condition, that is, the mineral is distributed throughout the rock. Figure 2 represents a specimen from Jamesville, N. Y. The rock is a drab dolomitic limestone. The cavities, as can be readily seen, are all sharp and angular, and range from one-quarter of an inch up to an inch or more in size. In the interior of these specimens a considerable

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amount of celestite is still present. Figures 3 and 4 represent a specimen (two views) from Split Rock, a short distance west of Syracuse, N. Y. In this specimen a very large percentage of the rock was celestite, as is indicated by the large number of cavities. In the interior the mineral is still to be seen. A comparison of these figures (3 and 4) with figure 1 shows that a very close similarity exists between the two occurrences. Figure 5 shows another specimen from Jamesville, N. Y., where the celestite appears disseminated in small irregular spots.*

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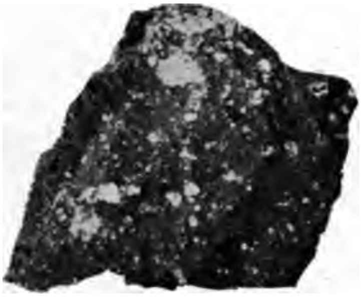

A study of these and other specimens shows first, that the celestite is or was actually distributed throughout the rock, or in other words, imbedded in the rock; second, that the cavities, which remain after the mineral has been removed by solution, conform for the most part to the original outline of the celestite; and thirdly, that many of these cavities are very sharply defined, being bounded by smooth surfaces. Therefore, the conclusion is forced upon one that *the celestite was no doubt deposited simultaneously with the rock material, and also that as the crystals of celestite formed, the soft rock material yielded and surrounded them on all sides. Such occurrences may, hence, be considered of primary origin.*

Further investigations as to the crystallography of the celestite in these localities, the amounts of the mineral actually present in the rocks and the origin of the sulphur which is associated with the celestite, especially at the Woolmith quarry, are in progress in this laboratory and will be reported upon as soon as feasible.

I am indebted to Dr. G. P. Burns for the photographs which accompany this paper.

**Mineralogical Laboratory, University of Michigan,**
**Ann Arbor, Mich., January, 1905.**

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* Compare figs. 1, 3, 4, 5 with those shown in a previous paper "The Occurrence of Celestite near Syracuse, N. Y., etc.," this Journal, lviii, 31, 33, 34, 1904; fig. 2 is repeated from that paper.

## ART. XXVII.—*A Note on Interference with the Bi-Prism;* by WILLIAM MCCLELLAN.

IN most descriptions of interference with the bi-prism the trouble which diffraction is likely to cause receives scant attention. It is true, reference is usually made to the fringes that are commonly found to border the field, but not as if they could seriously detract from the result. Some time ago, on setting up a prism on an optical bench, a colored center was obtained, and apparently no amount of adjusting would make it appear white. This, of course, proved the presence of something other than interference, that is, diffraction. The matter was studied a little, and an explanation found which is quite simple. It is obvious that the condition of the field as obtained from a given prism depends upon the relation of the distances between the prism, screen and light. The fact is well known to many experimenters, but no detailed note has ever been observed by the writer, in any text. This is probably due to the fact that the bi-prism is a lecture-room piece rather than one for the laboratory. The following explanation is suggested.

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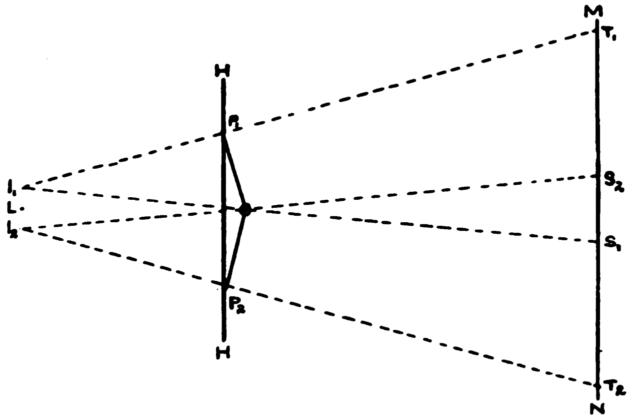

Let L (fig. 1) be a source of light, and I$_1$, I$_2$ its two images formed by the by-prism P$_1$ P$_2$. MN is a screen. We may treat the diagram as if I$_1$, I$_2$ were separate sources, as they might be if we could arrange constant phase relations. Light coming from I$_1$ will light the screen from S$_1$ to T$_1$ if we consider the prism set in an opaque holder HH. Similarly, light from $I_2$ will illuminate $S_2T_2$. The space $S_1S_2$ is lit by both sources and is therefore the interference field. It is necessary to notice however that as no light from $I_1$ can fall below $S_1$, the prism face $OP_2$ can be looked upon as an opaque screen for $I_1$. Consequently we find diffraction bands extending from $S_1$ into $S_1S_2$. In like manner fringes will extend inwards from $S_2$. Now it is easily seen that if the two sets of diffraction fringes should extend so far into $S_1S_2$ as to meet, there would be no clear field in which pure interference could be seen. The two kinds of bands would be superimposed, and neither would be seen as they are. This, of course, is precisely what does happen if conditions are not arranged to prevent it. It is easy to find what these conditions are.

Let the distance from light to prism be $a$, and that from prism to screen be $b$. Let the angle $OP_1P_2$ be $e$. Then if $d$ be the angle $I_1$, OL and $u$ the index of refraction, $d = (u-1)e$ which is half the angular space $S_1OS_2$. The half interference field on the screen is then $b(u-1)e$.

Now regarding $OP_2$ as a screen for the source $I_1$, and $x$ as the distance of the $2n$th diffraction band from the geometrical shadow,

$$x = \sqrt{\frac{b(a+b)}{a} 2n\lambda}$$

it is evident that if we are to have an open field for pure interference, this distance $x$ must be less than the half interference field, that is,

$$\sqrt{\frac{b(a+b)}{a} 2n\lambda} < b(u-1)e$$

or reducing

$$\frac{1}{a} + \frac{1}{b} < \frac{(u-1)^2e^2}{2n\lambda}$$

for any given prism, $u$ and $e$ can be measured. $n$ is a constant for all prisms, and is simply the number of that pair of bands for which the ratio of intensities is so close to unity as not to permit of separation by the eye. This value can be calculated or observed. Either method shows that six is a fair value for $n$. $\lambda$, of course, depends upon the light used. It should be noticed that while a prism with a large angle $e$, according to the formula, will give a clear space more easily, the interference lines will be narrower the larger the angle. This is shown by the expression for the width of interference lines, $\frac{\lambda}{2(u-1)e}$. For this reason the prisms supplied for this purpose usually have small angles, which give wider lines but a very narrow clear space.

Figures 2 and 3 will illustrate the above discussion. They are reproduced from photographs taken on the optical bench. using the eye-piece as an objective. Figure 2 shows the two

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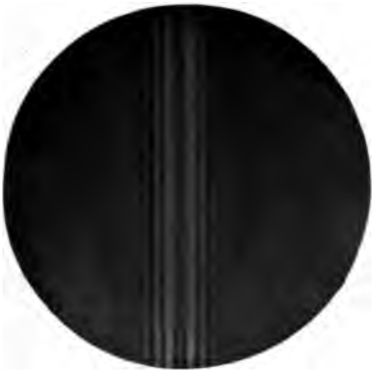

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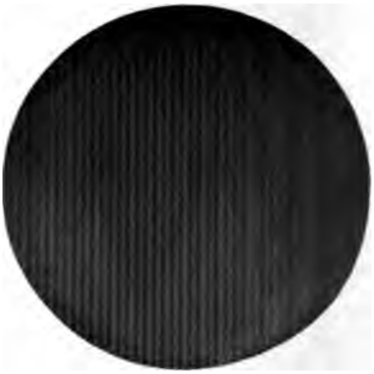

sets of lines superimposed; the center band could be made any color desired, by changing the distances a and b. Figure 3 shows a half field with complete separation. On the left the two sets of lines can be seen superimposed, while on the right the interference lines alone are seen. Another photograph, not reproduced, shows a whole field with very complete separation, the central portion covered with very fine interference bands.

**Randal Morgan Laboratory,**
**University of Pennsylvania.**

## ART. XXVIII.—*The Doughty Springs, a Group of Radium-bearing Springs, Delta County, Colorado;** by WILLIAM P. HEADDEN.

THE group of springs, known as the Doughty Springs, is situated on the right bank of the North Fork of the Gunnison River in Delta County, Colorado, about four and a half miles from the town of Hotchkiss. They are almost wholly unknown to the public, and are but little more than objects of curiosity to the people of the neighborhood. My attention was called to them about two years ago by H. E. Mathews, in whose company I first visited them.

The odor of hydrogen sulphide is noticeable for some distance from the springs, but the extensive sinter bed is a more striking feature, especially to persons more familiar with mineral springs in general.

A superficial examination of the surroundings, particularly of the face of the cliff, which rises immediately behind the springs to a height of 130 feet, suggests even more strongly than the sinter bed, that these springs or waters from some other source are heavily charged with salts and are now acting upon the sandstones and shales to a very readily observed extent.

The sinter bed is 400 feet long by 147 feet wide, measured at the widest part, with an average width of about 115 feet. The thickness of the bed where exposed along the river is about 20 feet, but increases a little as we approach the springs, showing that a general deposition is now taking place. There is but one instance of cone building and the little streams which flow across the surface of the bed have not formed elevated margins to mark their course.

The formation of the cone about this one spring is due to the fact that it is surrounded by a rank-growing grass, whose leaves and stems falling about it serve to catch and hold the sinter-forming material until cemented together, forming quite a compact sinter.

The sinter bed extends from the springs, which are situated near the base of the cliff, to the river, where it forms an almost perpendicular face. The river has encroached upon the bed by undermining and causing the overhanging sinter to break off; such broken-off pieces, 20 feet in width, are still remaining.

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* An abstract of a paper read before the Colorado Scientific Society, Jan. 13, 1905. This paper was presented by permission of the President of the College.

The cliff rises perpendicularly to a height of 130 feet immediately back of the springs, but is higher at points both above and below them; in structure it presents an alternation of sandstones and shales with a stratum of conglomerate near the top. This series probably belongs to the upper portion of the Dakota.

While the flow from the individual springs is not notably large, the aggregate flow of the group is very considerable. The large number of small springs in the group is probably due to impeded outflow, whereby the waters are forced to find various passages for their escape. According to my information, one spring issues in the bed of the river. All of the springs emit gases in moderate quantities, but the emission is continuous. In addition to the flow of the springs proper, small streams are issuing from the face of the sinter bed at very many places, in fact, almost throughout its entire length. Assuming this water to come from the springs, their actual discharge must be quite large, but it is not certain that this assumption is wholly correct. I have no doubt but that waters coming from the cliff, including some surface waters, do find their way into the springs under the present conditions, but the amount of this water is wholly insignificant, and without influence upon the flow of the springs. While I do not think that there is any significant quantity of surface water finding its way into these springs, it does seem probable that some of the waters represent mixtures of different springs. It is clearly evident that there are three distinct types of water represented by the analyses which I shall give. There is, however, a number of springs, how many I do not know, whose waters are intermediate in character between two of these types.

The gases emitted by these springs consist largely of carbon dioxide and hydrogen sulphide, but I have not yet submitted them to an examination. I am of the opinion that they will prove to be as interesting as the waters themselves or their deposits.

These springs are, so far as the writer is aware, wholly unknown to the general public, and have no individual names, but are spoken of collectively as the Doughty Springs. It is true that one of them is called the Black Spring, because the water as it lies in a basin adjoining the spring proper appears black; another is called the Bath Tub, because of its size and convenient depth for bathing; also, because there are good reasons to believe that the Indians used it for this purpose, for according to Mr. Doughty, the mud which had gradually collected in the bottom of the spring was found to contain an abundance of beads and Indian trinkets lost by the bathers. The Indians attributed great medicinal virtues to this and to the other springs also. A third spring is called the Drinking Spring, because the water of this spring is preferred to that of any of the others for this purpose. I do not know the reason for this choice, but those who are accustomed to it drink it very freely. This preference is probably another instance in which the general judgment has arrived at a correct scientific conclusion based upon some effect which it either cannot or never troubles itself to formulate. It will appear later that this is the most remarkable spring in the group and constitutes one of the three types to which I have alluded.

There are but three springs in the group whose waters are clear; they are the Black Spring, the Drinking Spring, and a smaller one designated the Alum Spring. The other springs show a pronounced milkiness. The presence of hydrogen sulphide would, according to general observation, account for this, especially in the case of springs having a small flow and presenting a large surface to the air, such as the Bath Tub, whose diameters are 19 and 27 feet respectively. Some of the smaller springs, however, having a comparatively large flow of water and gases—conditions tending to reduce this degree of milkiness, are more turbid than the Bath Tub, and suggest that the presence of hydrogen sulphide is not the cause of the milkiness, which is really the case. I shall subsequently show that it is almost wholly due to the separation of baric sulphate and not to sulphur set free by the decomposition of hydrogen sulphide.

The Black Spring is clear, but it is forming little or no deposit from its waters. While there is some deposit formed on the shale through which the spring issues, this deposit is almost pure sulphur and undoubtedly owes its origin to the oxidation of the sulphide. This spring has a basin contiguous to it, but the deposit forming in this is black (from which fact the spring obtains its name), and consists essentially of ferrous sulphide with manganous sulphide and a trace of zinc sulphide. The Alum Spring is clear, but its deposits are of an entirely different character from the sinter formed by the other springs. The Drinking Spring is perfectly clear and sparkling, and is actively depositing sinter outside of the spring. This sinter is practically pure baric sulphate.

The milkiness of the other springs is due to the separation of baric sulphate in an extremely fine state of division: this separation probably takes place before the waters actually come to the point of their discharge. The cause of the separation is probably to be found in the mingling of waters from different springs quite near to the surface. We have the Drinking Spring at one end and the Black Spring at the other, both clear, while the intermediate ones are turbid. The water of the Black Spring is different from that of the Drinking Spring, and a mixture of these waters would bring about the precipitation of baric sulphate. The precipitated baric sulphate is in an extremely fine state of division, and the flow of water and gas is sufficient to keep it in suspension and produce the milky appearance of the water.

The considerations which lead me to this conclusion are the following:

The Drinking Spring is perfectly clear and contains a very marked quantity of barium in solution. This spring is depositing a baritic sinter outside of the spring.

The other springs are turbid or milky. Their waters contain only a very minute trace of barium after the milkiness has disappeared. A baritic sinter is forming in and about these springs.

A spring designated as the Birds Nest is building a cone about its vent consisting very largely of baric sulphate precipitated within the spring and washed up and out by the outflowing gases and water. The water contains only a minute trace of barium.

A small amount of deposit was obtained from five gallons of water dipped from the Bath Tub; this deposit contained in whole numbers 25 per cent of baric sulphate and only a minute quantity of sulphur. The fine impalpable mud from the bottom of the Bath Tub contained almost 40 per cent of baric sulphate.

The foregoing facts convince me that the explanation offered to account for the milkiness of these springs is correct. It further seems to me to follow that water similar to that of the Drinking Spring is the source of the barium, while the precipitant is probably a water of the type of the Black Spring. If the precipitation takes place very near to the surface, it is possible that water of surface origin may participate in the precipitation.

I cannot give the number of springs in this group. The strip extending from the Drinking Spring to the Black Spring, a distance of 150 feet or more, is an area of general discharge with a number of well defined springs.

The waters of these springs are, at first, not very acceptable to the palate and the average person would have to acquire a taste for them. The characteristic in their taste is not due to the hydrogen sulphide. I do not know to what one can liken their taste, especially that of the Drinking Spring, which suggests to me simultaneously the taste of hydrogen sulphide and that of hydrogen peroxide.

All the springs of this group with the exception of the Alum Spring furnish drinkable waters, but the preferred ones are the Drinking Spring and the Black Spring. The water of the Alum Spring is so astringent that its character becomes apparent to one immediately upon tasting it.

### *Black Spring.*

This is the most westerly spring of the group of any size; its diameters are 30 and 48 inches respectively. The flow is not very strong and is accompanied by a continuous but moderate discharge of gas. The water is clear and has a temperature of 17·5° C.

The presence of the following substances is not noted in the analyses: sulphides other than hydrogen sulphide; titanic, phosphoric, and dithionic acids. I could not examine the waters until the samples had become so old that a determination of the sulphides and the dithionic acid would have been of but little or no value.

I determined the dithionic acid in the water of the Black Spring while the sample was comparatively fresh; its value, however, is not great, for the sample was already several days old Phosphoric acid is present in minute traces; titanic acid also, but the reactions for the latter were very faint, and may have been erroneously interpreted. I did not detect either caesium or rubidium in the amounts of water used, from three to six liters.

#### ANALYSIS OF BLACK SPRING.

*Calculation of Cations.*

| | Per liter. | | Monivalent ions. |
|---|---|---|---|
| Na | 1·1978 | 0·051964 | 0·051964 |
| K | 0·0589 | 0·001504 | 0·001504 |
| Li | 0·0016 | 0·000224 | 0·000224 |
| $NH_4$ | 0·0013 | 0·000074 | 0·000074 |
| Ca | 0·1261 | 0·003152 | 0·006304 |
| Ba | None | | |
| Sr | 0·0035 | 0·000039 | 0·000079 |
| Mg | 0·0609 | 0·002500 | 0·005000 |
| Fe | 0·0012 | 0·000021 | 0·000042 |
| Al | 0·0046 | 0·000168 | 0·000504 |
| Mn | 0·0040 | 0·000072 | 0·000144 |
| Zn | Trace | | |
| Sum | 1·4599 | | 0·065839 |

### *Calculation of Anions.*

| | Per liter. | | Monivalent ions. |
|---|---|---|---|
| Cl | 0·8157 | 0·023009 | 0·023009 |
| Br | 0·0147 | 0·000184 | 0·000184 |
| I | Trace | | |
| $SO_4$ | 0·2731 | 0·002843 | 0·005686 |
| $SiO_3$ | 0·0235 | 0·000308 | 0·000616 |
| $BO_2$ | 0·0001 | 0·000003 | 0·000003 |
| $S_2O_3$ | 0·0108 | 0·000096 | 0·000182 |
| Sum | 1·1397 | | 0·029680 |

| | |
|---|---|
| Sum of cations | 0·065839 |
| Sum of anions | 0·029680 |
| Excess cations | 0·036159 |

The excess of cations, 0·036159, equals $CO_3$ ions expressed as monivalent ions or 0·018079 bivalent ions corresponding to 1·08474 grams $CO_3$ equal to 0·794438 gram $CO_2$ combined as neutral carbonates.

| | |
|---|---|
| Total $CO_2$ found was | 2·5660 |
| $CO_2$ combined as neutral carbonates | 0·7944 |
| | 1·7716 |
| $CO_2$ combined as bicarbonates | 0·7944 |
| $CO_2$ wholly free per liter | 0·9772 |

The $CO_2$ wholly free corresponds to 496·84$^{cc}$ per liter at 0° C. and 760$^{mm}$ pressure.

Hydrogen sulphide considered as wholly free equals 0·0492 gram or 32·12$^{cc}$ per liter. Specific gravity at 16° 1·00400. Total solids 3·6825 grams per liter.

## *The Drinking Spring.*

The water of this spring is by far the most interesting one of all the group: it is clear and limpid with a decided odor of hydrogen sulphide. The discharge of gas is moderate but constant. There are smaller springs of the same character in its immediate vicinity. The spring is nearly circular with a diameter of 12 to 14 inches.

### ANALYSES OF DRINKING SPRING.

*Calculation of Cations.*

| | Per liter. | | Monivalent ions. |
|---|---|---|---|
| Na | 1·0571 | 0·045863 | 0·045863 |
| K | 0·0617 | 0·001576 | 0·001576 |
| Li | 0·0031 | 0·000446 | 0·000446 |
| $NH_4$ | 0·0012 | 0·000068 | 0·000068 |
| Ca | 0·1057 | 0·002636 | 0·005272 |
| Ba | 0·0132 | 0·000096 | 0·000192 |
| Sr | 0·0066 | 0·000075 | 0·000150 |
| Mg | 0·0394 | 0·001615 | 0·003230 |
| Fe | 0·0007 | 0·000013 | 0·000026 |
| Al | 0·0005 | 0·000018 | 0·000054 |
| Mn | 0·0016 | 0·000030 | 0·000060 |
| Zn | Trace | | |
| Sum | 1·2908 | | 0·056937 |

*Calculation of Anions.*

| | Per liter. | | Monivalent ions. |
|---|---|---|---|
| Cl | 0·7005 | 0·019762 | 0·019762 |
| Br | 0·0052 | 0·000065 | 0·000065 |
| I | Trace | | |
| $SO_4$ | 0·6252 | 0·006511 | 0·013022 |
| $SiO_3$ | 0·0266 | 0·000348 | 0·000696 |
| $BO_2$ | 0·0075 | 0·000174 | 0·000174 |
| Sum | 1·3652 | | 0·033719 |

| | |
|---|---|
| Sum of cations | 0·056937 |
| Sum of anions | 0·033719 |
| Excess of cations | 0·023218 |

The excess of cations, 0·023218, equals $CO_3$ ions expressed as monivalent ions or 0·011609 bivalent ions corresponding to 0·69654 gram $CO_3$ equal to 0·5108 gram $CO_2$ combined as neutral carbonates.

| | |
|---|---|
| The total $CO_2$ found was | 3·0800 grms. |
| Less $CO_2$ combined as neutral carbonates | 0·5108 |
| | 2·5692 |
| Less $CO_2$ combined as bicarbonates | 0·5108 |
| $CO_2$ wholly free per liter | 2·0584 |

The $CO_2$ wholly free, 2·0584, corresponds to 1047·53$^{cc}$ at 0° C. and 760$^{mm}$ pressure.

The hydroden sulphide considered as wholly free equals 0·0471 gram per liter equal to 30·88$^{cc}$ at 0° C. and 760$^{mm}$ pressure. The specific gravity at 15·5° was 1·00377. The total solids = 3·3525 grams per liter.

Deposits of various salts occur rather abundantly on the face of the cliff; these are for the most part easily soluble salts, but some of them are more difficultly soluble. Gypsum occurs occasionally but is not common.

These salts might owe their formation to surface waters finding their way through the strata to the face of the cliff. The dip and character of the strata are such that if this be the case the waters must come from considerable distances. On the other hand, the waters saturating the strata might be spring waters, in which case the incrustations ought to resemble the deposits from the spring waters. These considerations motived me to examine a few of these deposits and led to some very interesting observations.

An incrustation occurring on the face of the sandstone stratum 150 to 200 feet east of the Drinking Spring and five feet or more above the upper margin of the talus soil was found to contain 2·50 per cent of sulphur with calcium, barium, potassium, lithium and sodium. Though this sample was collected 150 feet or more from the nearest observed spring and from the face of a compact sandstone stratum under conditions precluding accidental deposition, its qualitative composition is strongly suggestive of the matter held in solution by the water of the Drinking Spring. The appearance of this incrustation on the face of the sandstone fairly raises the question of the source of these waters, i. e. are they waters finding their way along and through the strata, or are they forced into the strata from below? I am inclined to the view that they come from greater depths, but the springs themselves do not indicate a high pressure.

Another sample collected 50 feet or more up on the face of the cliff proved to be the mineral mirabilite. It was well crystallized and was not associated with other minerals. It is not at all rare to find this mineral deposited from some of our alkali waters in crystals five or six inches long, but in this case it probably came from the stratum of shale.

Another deposit collected from the rocks at the base of the cliff immediately back of the Black Spring had an entirely different composition. It was this that led me to examine the water designated as the Alum Spring.

This deposit occurred associated with well defined crystals of gypsum; it was white, pasty, and astringent to the taste. When a coil of clean iron wire was brought into its aqueous solution, hydrogen was set free quite rapidly. A solution of aluminic sulphate treated in this manner will liberate hydrogen, but not nearly so rapidly as this solution. A comparative test showed the evolution of hydrogen from a solution of aluminic sulphate to be less than one fifth as rapid. This deposit placed in contact with cotton cloth or paper destroys it.

The analysis of this sample presented some difficulties and the footing of the analysis is over one hundred. The sample was dried for three days at the temperature of the room; its weight was nearly constant during the last day.

The analytical results were as follows:

| | Per cent. |
|---|---|
| Loss on drying in water oven for ten hours | 29·61 |
| Loss on drying in air-bath at 147° for two hours | 15·35 |
| Insoluble in water | 2·72 |
| $SO_3$ | 32·89 |
| $Fe_2O_3$ | 1·16 |
| $FeO$ | Trace |
| $Al_2O_3$ | 6·71 |
| $CaO$ | 0·69 |
| $MgO$ | 3·33 |
| $Na_2O$ | 4·68 |
| $K_2O$ | 0·32 |
| $Li_2O$ | Heavy trace |
| Ignition with addition of lead oxide | 4·45 |
| | 101·91 |

The reactions of this material are those of an alum, and the composition is between that of mendozite and pickeringite. The material did not seem to me to justify a repetition of the analysis, especially as I intended to visit the locality again to determine, if possible, whether there is a spring at this point whose waters would account for the formation of such a deposit as this. On my next visit I found that heavy rains following periods of freezing and thawing had caused large quantities of material to come down from the cliff above, and the point where I had obtained this sample was covered deeply under mud and rocks. We succeeded in digging two holes from which we obtained samples of water: one of them was clear but the other was turbid, due to the presence of a white precipitate. Neither of these samples was satisfactory, but I could not obtain better ones. The following analysis serves thoroughly well to show the character of the water collected, though it is not so complete as some of the others. The sample was not from a definitely located spring, and the analysis given is of as much value as a fuller one would be.

### ANALYSIS OF ALUM SPRING.

*Cations.*

| | Per liter. | | Monivalent ions. |
|---|---|---|---|
| Na | 0·4561 | 0·019786 | 0·019786 |
| K | 0·0216 | 0·000551 | 0·000551 |
| Ca | 0·4089 | 0·010198 | 0·020396 |
| Mg | 0·1888 | 0·007750 | 0·015500 |
| Fe | 0·1485 | 0·001860 | 0·003720 |
| Al | 0·3036 | 0·011203 | 0·033609 |
| Sum | 1·5275 | | 0·093562 |

*Anions.*

| | | | |
|---|---|---|---|
| Cl | 0·2790 | 0·007869 | 0·007869 |
| $SO_4$ | 3·5275 | 0·036608 | 0·073216 |
| $SiO_3$ | 0·0745 | 0·000975 | 0·001950 |
| | 3·9810 | | 0·083035 |

| | |
|---|---|
| Sum of cations | 0·093562 |
| Sum of anions | 0·083035 |
| Excess of cations | 0·010527 |

The excess of cations, 0·010527, expressed as monivalent ions correspond to 0·005264 bivalent $CO_3$ ions or 0·2316 gram $CO_2$ per liter as neutral carbonates. Specific gravity at 15·5° C. 1·00546. Total solids 5·7401.

If the calcium were removed from this water in the form of gypsum it would give rise to just such a mixture as we actually found.

The sample which remained milky was not analyzed, but it was thoroughly shaken and a portion of it filtered, and the white precipitate examined; it consisted principally of aluminic hydrate.

As the point at which I had formerly found the white, pasty mass, an analysis of which has already been given, was buried under a mass of débris, I of course failed to obtain more of it, but I found at this place masses of the mineral alunogen. This mineral occurs abundantly at the base of the conglomerate previously mentioned, and the specimens found at this time may have come from this source.

The most interesting feature of these springs is the sinter bed which they have formed, of which there is probably more than a million cubic feet remaining at this time. An analysis of a general sample taken from the face next to the river gave the following results:

ANALYSIS OF GENERAL SAMPLE OF SINTER FROM FACE OF BED NEXT TO THE RIVER.

| | Per cent. |
|---|---|
| Sand and $SiO_2$ | 0·51 |
| Organic matter | 2·29 |
| $CO_2$ | 39·39 |
| Cl | Trace |
| $SO_3$ | Trace |
| CaO | 48·84 |
| SrO | 1·16 |
| BaO in HCl solution | Trace |
| MgO | 1·37 |
| $Fe_2O_3$<br>$Al_2O_3$ | 0·20 |
| MnO | 0·62 |
| $Na_2O$ | Trace |
| $Li_2O$ | Trace |
| $BaSO_4$ | 5·42 |
| | 99·80 |

Other general samples from different parts of the bed were tested and baric sulphate found to be present in all of them, the percentage ranging from 3·25 to nearly 10·0 per cent. As the sinter was richer in baric sulphate as we approached the end of the bed where the Drinking Spring is located, I took two samples, one from near the spring and the other at the spring, and analyzed them with the following results:

ANALYSIS OF SINTER TAKEN 8–10 FEET FROM THE DRINKING SPRING.

| | Per cent. |
|---|---|
| Organic matter with a little free sulphur | 3·43 |
| $CaCO_3$ | 26·46 |
| $BaSO_4$ | 66·98 |
| Fe, Mn, Na, K and Li not determined | [3·13] |
| | 100·00 |

ANALYSIS OF SINTER TAKEN WITHIN 2½ FEET OF THE RIM OF THE DRINKING SPRING.

| | Per cent. |
|---|---|
| Organic matter with a little sulphur | 3·11 |
| $CaCO_3$ | 1·84 |
| $BaSO_4$ | 94·62 |
| Mg, K, Na and Li | Traces |
| | 99·57 |

The spring designated the Bird's Nest is building a cone of this baritic sinter: it has the following composition:

| | Per cent. |
|---|---|
| Organic matter, etc. | 7·82 |
| $CaCO_3$ | 43·39 |
| $BaSO_4$ | 48·79 |
| Sr, K, Na and Li | Traces |
| | 100·00 |

The Bath Tub furnishes the finest samples of this baritic sinter. The spring is lined with a pure cellular barite. The sample which I used as a source of this barite for analysis was from the Bath Tub, but was chosen to represent an average sample of this sinter as it occurs near the springs.

ANALYSES OF SINTER FROM THE BATH TUB.

| | Per cent. |
|---|---|
| Soluble in acetic acid | 15·46 |
| Soluble in HCl conc., not soluble in acetic | 1·33 |
| Insoluble, $BaSO_4$ | 83·21 |
| | 100·00 |

*Analysis of the insoluble portion.*

| | |
|---|---|
| $SiO_2$ | 3·25 |
| $SO_3$ | 32·25 |
| $Al_2O_3$ <br> $Fe_2O_3$ | 0·80 |
| BaO | 63·00 |
| CaO | 0·30 |
| SrO | 0·45 |
| MgO | Trace |
| $K_2O$ | 0·17 |
| $Na_2O$ with heavy trace of lithia | 0·29 |
| | 100·51 |

The barium determination is too high; the chromate should have been reprecipitated a second time.

The examination of these samples of sinter show that the bed passes from a calcareous sinter carrying a few per cent of baric sulphate to a pure barite sinter at some of the springs. This I believe to be a unique fact. Frequent mention is made of the occurrence of barium in mineral springs, mostly in traces, but I have found mention of only one water which deposited baric sulphate, a mine water in England.

I have stated that I regret not having yet examined the gases given off by these springs. I am fully convinced that they contain helium, for these waters contain, as I shall now show, comparatively abundant quantities of radium.

The close relationship between barium and radium and the well-known fact that barium possesses the property of carrying down other substances with it when precipitated from its solution and radium in a very high degree, made it almost certain that I would find this sinter to contain radium provided any at all were present in the springs.

I was forced to depend upon its action on the photographic plate in testing for it. The action of the sinter as it was broken from the bed, always from points near or at the springs, was of course weak compared with the action of Gilpin County pitchblende, but it was always present and could be seen during the development of the plate even if it were invisible after fixing and drying,

In one experiment made to test the action of the sinter in comparison with that of pitchblende the plate was covered with two thicknesses of black paper and a piece of pasteboard and the exposures made for five days; the radiograph obtained with the pitchblende was distinct but not sharp; the plate exposed to the action of the sinter showed the stencil used while it was being developed, but not when fixed and dried.

I next undertook the preparation of radiferous barium chloride. For this purpose I fluxed 13 pounds of sinter with sodic carbonate, washed, dissolved in HCl, removed silica and iron by usual methods and crystallized out the baric chloride; the yield of crude $BaCl_2$ was eight pounds. This was subjected to fractional crystallization at last from HCl solution. When the mass of $BaCl_2$ amounted to rather less than 2 ozs. it was allowed to stand for 15 days to regain its $\beta$ and $\gamma$ rays and then tested. This preparation gave an impression upon the plate after an exposure of 2½ days comparable to that made in five days by pitchblende. The distance between the film and the salt was from 0·25 to 0·5 centimeters and the plate was covered with two thicknesses of black paper. I did not deem it necessary to carry this work further for the purposes of this immediate work.

So far as I am able to discover, this group of springs is unique in that it is depositing a baritic sinter, and also in the presence of radium in comparatively large quantities.

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## ART. XXIX.—*The Error of Collimation in the Human Eye;* by C. S. HASTINGS.

[The references H in the following pages are to the Handbuch der Physiologischen Optik von H. von Helmholtz. Zweite Auflage, 1896.]

ONE of the most curious imperfections of the human eye, of the many discovered or investigated by Helmholtz, is that of an unfailing inclination of the line of sight to the axis of symmetry of the cornea (H. p. 17), or, what appears to be essentially the same thing, to the geometrical axis of symmetry of the whole eye (H. pp. 108, 109). There is, it is true, no reason for surprise that such an error should exist, since, if we suppose, as we are obliged to do, that the present structure of the eye is the result of a long process of evolution, we ought to expect the survival of imperfections which, too minute to impair the effectiveness of the eye as a sense organ, would therefore be too minute to serve as incentives to farther development. Such surviving imperfections would be called errors when we regard the eye as an optical instrument; and Helmholtz has shown that no error which can be named by the optician is absent from the eye. On the other hand, this eminent investigator has shown that these errors are always so small, in a normally formed eye, as not to impair the precision or visual perceptions with the eye of its present size. This point may be emphasized by the following consideration. If it were required to remodel the eye so as to double its present power, it can easily be shown that this would necessitate an increase of volume to fifteen or twenty times its present value. In view of the enormous difficulties to be met in nourishing and protecting such an organ with a retention of its transparency, we may well conclude that the balance between physiological cost and utility has already been attained, in short, that the closest approach to practical perfection has been reached long ago, even in the protracted history of evolution.

The particular error, however, which is the subject of our consideration and which would be known to opticians as an error of collimation, is distinguished from nearly all others in two peculiarities; first, it is the easiest of all errors in an ordinary optical instrument to eliminate, and second, it is systematic, i. e. it is of such a character that the axis of vision always lies on the nasal side of the geometrical axis outside of the eye. It is this systematic character of the error which gives it its particular interest and for which we feel ourselves prompted to seek a reason.

The first step in an investigation with this end in view is to find the average value of the error. Helmholtz himself (H. p.

19) measured this angle for three eyes only, but Dr. Uhthoff (H. p. 22) adds four, and H. Knapp (H. p. 109) gives data from which we may deduce, with considerable confidence, four more. We thus have eleven cases of which the average value of the angle ($\alpha$) is 5°·36. This is an insufficient number to serve as the basis of any important conclusions, especially in view of their great irregularity of values; it seemed desirable, therefore, to collect a larger number of instances. In this work Professor F. E. Beach kindly aided me with great skill, and to him is due more than half of all the measurements of which the results follow.

The method employed was quite like that devised by Helmholtz (H. pp. 15–19), except that we used a filar micrometer instead of an ophthalmometer. Both methods were tried, but, notwithstanding the obvious advantages of the double image instrument, the former was found quite as accurate and materially more rapid. With this arrangement we found for 52 eyes the following results:

I. There was no case of reversal in sign of $\alpha$, that is, the axis of vision, extended outwards, always lies on the nasal side of the axis of symmetry of the cornea.

II. The value of $\alpha$ varies greatly. The smallest value which we found was 1°·25 and the largest 7°·76. There was no evidence of a systematic difference in the numerical values of the angle for the right and the left eye.

III. The mean value for the 52 eyes examined was 3°·98.

The mean value is much less than that of the German measures; this may be owing to racial differences—it is well known that the average separation of the eyes is less for Americans than for Germans—or it may be owing simply to the small number of cases in the earlier group. However this may be, it seems that the best attainable value at present is the weighted mean of these two averages, namely:

$$\alpha = 4^\circ{\cdot}2$$

We shall assume in our further studies, therefore, that a line drawn from the second nodal point in the normal eye to the center of that small region of the retina to which the sharpest visual perceptions are confined—the *fovea centralis*—lies wholly on the temporal side of the geometrical axis of the eye and inclined to it at an angle of 4°·2; moreover, as necessarily involved with this assumption, that a line drawn outwards from the first nodal point to the point of fixation lies wholly on the nasal side of the axis at the same angle of inclination. This angle we may call, for convenience, the constant of collimation for the normal or schematic eye (H. p. 140).

Closely connected with the constant of collimation in the discussion of a variety of optical phenomena which I shall consider later, is the question of the position of the pupil of the eye. Here too, we lack sufficient data for establishing any conclusion. As far as is known to me, only three eyes have been investigated in this particular, and all of these by Helmholtz (H. p. 29); and as he found in two of the three that the center of the pupil falls very near the axis of vision, and in the third very near the axis of the eye, no result could be less determinate. Were the base of the cornea centered upon its axis of rotation as Helmholtz concluded from his limited number of observations (H. p. 19, relation of angles $\alpha$ and $\beta$), the determination of this element would be very easy; indeed, a simple inspection shows that the pupils of practically all eyes, at least when not dilated, are strongly displaced towards the nasal side of the iris. But we found no such simple relation between the axes of the cornea and of the iris; hence it seemed necessary to make a rather extended series of measures for a foundation for precise conclusions.

Helmholtz's method of determining this element by use of his ophthalmometer is somewhat laborious and subject to considerable uncertainties, if not to errors, from changes in pupilar diameter during the measurements. This consideration, together with the fact that statistical information founded upon numerous observations of moderate accuracy is of far greater value than an accurate determination of individual peculiarities, led me to adopt a different method, which may be described as follows.

A telescope provided with a filar micrometer is placed at a distance from the eye to be measured, which is large compared to the linear dimensions of the eye. The telescope has directly below its objective a small adjustable mirror which, illuminated by a conveniently placed light, serves as a luminous source itself. When the observed eye is fixed upon the middle of the objective of the telescope, the observer sees, with properly adjusted telescope, a sharply defined image of the pupil with a bright point image of the mirror near its center. Two parallel wires of the micrometer are brought within a convenient small distance of each other, and the telescope so directed that these wires appear to be symmetrically placed upon the pupil; then the point image will, in general, appear to lie slightly on the nasal side of a point midway between the wires. In a few cases the bright point will appear exactly half way between the wires, and even, in very exceptional cases, with a very slight displacement towards the temporal side.

Fig. 1 illustrates the general appearance when the nose lies in the direction indicated by the arrow. When a satisfactory adjustment of this kind is secured, an estimate is made of the apparent displacement of the center of the pupil towards the temporal side in terms of tenths of the separation of the wires. A subsequent determination of the absolute value of the interval between the wires yields the real displacement. In the observations which were made by Professor Beach, as well as in those made by myself, the reduced interval was $\cdot075^{cm}$, so the probable error of our measures may be estimated at about one-tenth of this quantity.

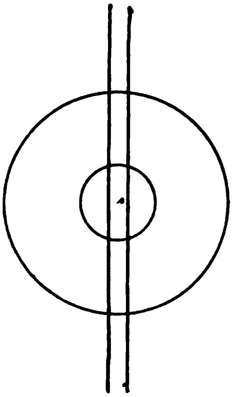

FIG. 1.

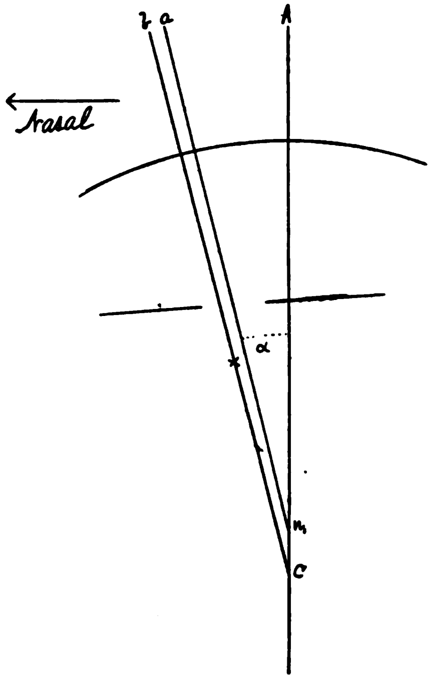

FIG. 2.

In the reduction of the observations it was assumed that the radius of the cornea was, in every case, the same as that of the schematic eye, namely, $0{\cdot}7829^{cm}$. Such an assumption was not necessary, since it would have been easy to determine this element for each case, but it was convenient and could lead to no error which could become significant in any considerable group of measures. The method of reduction will appear from reference to fig. 2. Here AC represents the axis of an eye with the geometrical center of the cornea at C and its first nodal point at $n_1$. The direction $n_1\, a$ will be that of the source of light and of the observing telescope. The image of the source of light will lie on the line $Cb$, which is essentially parallel to $n_1 a$, at a point midway between C and the surface of the cornea. Now if the center of the pupil were on the line of vision $n_1 a$, it would appear displaced towards the temporal side by a distance equal to the interval separating $n_1 a$ and $Cb$, or by $n_1 C \sin \alpha$. In the schematic eye the distance from $n_1$ to C is $0{\cdot}0861^{\mathrm{cm}}$. Since $\alpha$ is known for all the eyes observed, the relation of the position of the center of the pupil to the point where the line of vision pierces the plane of the pupil is readily determinable.

The results from the forty-eight eyes thus investigated appeared highly irregular. Yet a careful analysis brings us to a conclusion which may be stated with considerable precision. There were only two eyes in which the centers of the pupils were found to be quite certainly, although by a small amount, on the temporal side of the axis of symmetry, and these belonged to different individuals. On the other hand, only a single eye was found to have the center of its pupil quite distinctly on the nasal side of the line of vision, a peculiarity not shared by its companion. In this exceptional case the apparent displacement towards the nose was strikingly obvious to every casual observer. The mean position of all the forty-eight was almost exactly midway between the axis of symmetry and the line of vision. This relation, so simply stated, was not dependent upon the value of $\alpha$. This was proved by the fact that when all the observations were arranged in three equal groups according to small, medium and large values of the constant of collimation, each group was found to yield almost exactly the same rule.

The center which has been determined is, of course, the center of the virtual image of the pupil as seen through the cornea; but the rule holds true also for the real position of the pupil. It is not improbable that the center of a dilated pupil is not in quite the same place as one adjusted to a well-lighted room, but that is of minor importance in the questions which have led to this investigation.

For a further study of certain phenomena of vision I shall assume, as a generalization of the schematic eye of Helmholtz:

1st. That its constants as regards accommodation and wavelengths are defined by the tables given in the preceding number of this Journal.

2d. That the collimation error is $4^\circ{\cdot}2$ on the nasal side.

3d. That the pupil is centered on a line which bisects the angle between the axis of symmetry and the line of vision.

Yale University, March, 1905.

## Art. XXX.—*A New Form of Electrode for Lead Storage Cells;* by H. M. Dadourian.

It was desired to build up a battery of lead storage cells, to be used in the Sheffield Physical Laboratory, for constant potential. After considering several types of cells, one described by Feussner* was adopted. But the electrodes of these cells were inconvenient on account of the falling off of the paste. This objection was done away with by designing a new form of electrode, which has given such satisfactory results that it is thought it may be of interest to others.

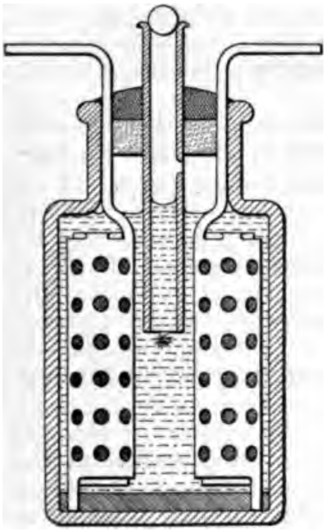
Fig. 1

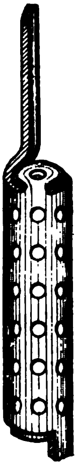
Fig. 2

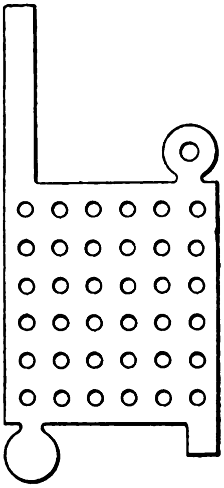
Fig. 3

A meridian section of a complete cell is shown in fig. 1. Fig. 2 is a perspective view of one of the electrodes, which are $50^{mm}$ long and are cut out of lead tubing $12^{mm}$ in diameter.

After being packed up with a paste made of lead oxide (litharge) and sulphuric acid of sp. gr. 1·20, a couple of these electrodes are placed in a glass bottle, $80^{mm}$ high and $45^{mm}$ in diameter. The electrodes are held in position by means of a layer of pitch at the bottom and a cork in the neck of the bottle. A small hole in the middle of the glass tube, which is in the center of the bottle, serves as an outlet for the gases which form in the cell.

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* Feussner, Sammlung Electrotechnische Vorträge, vol. i, p. 139.

The electrolyte, which is sulphuric acid of sp. gr. 1·20, comes into contact with the paste inside the electrodes through a number of holes, in the latter, of $3^{mm}$ diameter. A layer of Rowland's Universal wax* pasted on to the cork keeps the acid from creeping out. The electrodes can be made more easily of sheet metal by cutting in the form shown in fig. 3, then rolling it into a cylinder. In case it is desired to make a great number of these cells, a die may be made by which sheet metal can be punched out into the desired shape.

These cells have a capacity of about one ampere-hour and give a potential difference of a little over two volts. They keep this potential difference for several months without recharging.

I wish to express my thanks to Professors C. S. Hastings and H. A. Bumstead for their kind interest in and valuable suggestions on this work.

Sheffield Scientific School of Yale University,
March, 1905.

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* Ames and Bliss, A Manual of Experiments in Physics, p. 496.

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## Art. XXXI.—*Chrysoberyl from Canada*; by Nevil Norton Evans.

The mineral chrysoberyl is not one of very limited occurrence, but as yet it has not been reported from any Canadian locality, although rocks apparently similar to those in which it is found elsewhere occur over large areas in Canada. When therefore this mineral was identified in a rock from the Province of Quebec, it was thought well to analyse and describe it, so that the species from this locality might be compared with the same species from other places. The facts concerning its occurrence have been kindly supplied by Dr. F. D. Adams of McGill University, who collected the specimens.

The locality where the chrysoberyl was found is situated in the County of Maskinonge in the Province of Quebec, about 100 miles in a northerly direction from Montreal. It is thus beyond the limit of the settled country and in the woods, in a district which has not as yet been surveyed into townships. The spot is situated on the Rivière du Poste, a tributary of the River Matawin; this river in its turn is a tributary of the St. Maurice River, which runs into the St. Lawrence at the town of Three Rivers. It is about one mile below the forks of the Rivière du Poste, where the streams from Lac Long and Lac Clair run together, and is thus about thirteen miles in a straight line north of the point where the Rivière du Poste joins the Matawin. This whole region forms part of the great Laurentian peneplain and is underlain by Laurentian gneisses which, in this district, hold in places a few small bands of crystalline limestones. At the locality where the chrysoberyl occurs, the country rock consists of a series of quartzose gneisses; these present a considerable variation in character, being often highly garnetiferous, and they are associated with bands of quartzites. The whole series strikes N. 40–45° W. and has a high east dip. The gneiss, where the river crosses it here, is cut by great veins and dikes of pegmatite; these are composed of quartz, orthoclase and a white mica, with black tourmaline and the chrysoberyl as accessory constituents. The pegmatite, as is not uncommonly the case with this rock, often shows a rapid variation in size of grain from place to place. The chrysoberyl is not abundant, but occurs in well-defined crystals.

The rock specimen brought to Montreal contained two individuals of the chrysoberyl; careful chipping brought out the larger in two fragments and some small chips. The two principal fragments were fitted together and weighed 55 grams. This individual, about half of which is uninjured, has almost exactly the form of a hexagonal prism, apparently quite similar to the one figured in Dana's System of Mineralogy, 1885, fig. 155, terminated at each end by a hexagonal pyramid and end face; it méasures an inch and a half across and an inch and a quarter in the direction of the pseudo principal axis; the faces of the pseudo-prism, three of which are almost perfect, give an angle of 120° with the contact goniometer (they are not sufficiently smooth for more accurate measurement), and a seam, running vertically through the middles of two opposite prism faces, two of the pyramid faces, and the end faces, seems to be a plane along which the crystal has at one time been fractured, one-half having been slid along about 1/25 inch from its original position; there is, however, no sign of diminished coherence along this plane now. The material of the crystal is apparently fairly pure except for thin films of iron oxide running through it, and some orthoclase which penetrates it on one side.

The cleanest of the chips were chosen for analysis and were ground to a very fine powder in a specially hardened steel mortar; the powder was subsequently boiled with hydrochloric acid, filtered, washed and dried, to free it from the very considerable quantity of steel abraded from the mortar. The method of analysis employed was a slight modification of that given by Penfield and Harper in this Journal (3), xxxii, p. 114 (1886). After several preliminary trials, two analyses were made of the mineral, in each of which about 0·15 grams of the powder was fused in a platinum crucible for several hours with a large quantity of potassium disulphate, the fusion was extracted with dilute sulphuric acid, and the insoluble material, apparently silica, was filtered out and weighed. It amounted to a few tenths of a per cent and was deducted from the weight of mineral originally dissolved, the percentage of the other constituents being calculated to the remainder. The iron, alumina and beryllia were then precipitated with ammonia, the precipitate washed and redissolved in hydrochloric acid, the solution being then evaporated in a porcelain dish until crystallization just commenced. To this an excess of a strong solution of sodium hydrate, prepared from the metal in platinum, was added; the porcelain dish was used here, as several experiments showed that platinum dishes were attacked to a considerable extent. The mixture was diluted somewhat with cold water, and filtered; the precipitate was redissolved in hydrochloric acid and subjected to the same treatment as before, the filtrate obtained being added to that previously obtained. The precipitate was redissolved, reprecipitated with ammonia and treated in the usual way, giving the iron. The combined filtrates from the two precipitations by sodium hydrate were poured into a liter of boiling water, the boiling continued one hour, and the perfectly white beryllia filtered out, washed, ignited and weighed. The filtrate from the beryllia was boiled again for a short time to make sure that the precipitation of beryllia was complete, was then slightly acidified with hydrochloric acid, evaporated to a small bulk, and the alumina precipitated with ammonia and determined in the usual way. Tests were applied for calcium and magnesium, but neither was found.

The two analyses agreed very closely and the mean was as follows:

| | |
|---|---|
| BeO | 17·78% |
| $Al_2O_3$ | 76·76 |
| $Fe_2O_3$ | 6·07 |
| | 100·61 |

The specific gravity of the mineral was 3·52.

The iron was all calculated as ferric, and this probably accounts in part for the results being high, but no method could be devised for determining the ferrous iron present. No doubt also small quantities of material were dissolved from the dishes and beakers used; their use, however, seemed unavoidable, as platinum was attacked to such a marked extent.

Macdonald Chemical Department,
McGill University, Montreal.

## Art. XXXII.—*Souesite, a native iron-nickel alloy occurring in the auriferous gravels of the Fraser, province of British Columbia, Canada;* by G. Chr. Hoffmann, of the Geological Survey of Canada.

[Communicated by permission of the Acting Director, Dr. R. Bell.]

In washing the material obtained in dredging for gold in the Fraser river, two miles below Lillooet, Lillooet district, in the province of British Columbia, it has been found that there remains, at the time of cleaning up, a fine, heavy, greyish sand, having a metallic aspect. A sample of this sand, which was sent to the writer for identification, has been examined and found to consist, essentially, of an aggregation of small, very irregular-shaped, rounded grains of an iron-nickel alloy and small to minute, flattened, rounded, steel-grey, glistening scales of native platinum; intermingled with which were some minute, bright, steel-grey colored, irregular-shaped, flattened grains of iridosmine, a few flattened grains of native gold, some minute, partially rounded, crystals of magnetite, a few equally small grains of ilmenite, and a few particles of quartz and of garnet. Of the foregoing, the grains of the iron-nickel alloy constituted, approximately, forty-seven per cent, and those of the native platinum forty-three per cent, by weight, of the whole; the grains of iridosmine, native gold, magnetite, ilmenite, and of quartz and garnet, making up the balance of ten per cent.

This iron-nickel alloy occurs, as above described, in the form of small, very irregular-shaped, rounded grains, the largest not exceeding a millimeter and a half in diameter, whilst many, indeed the greater number, were of far smaller dimensions, and others were of microscopic minuteness. It has a faint yellowish steel-grey color, and a submetallic lustre; is strongly magnetic, and malleable. Its specific gravity, at 15·5° C., is 8·215. The mineral is but very slightly acted upon by hydrochloric acid in the cold; upon the application of heat, however, it very slowly passes into solution. It is readily attacked by dilute nitric acid, even in the cold, and is easily and completely dissolved by it on heating.

The mean of two very closely concordant analyses, conducted by Mr. F. G. Wait, upon very carefully selected material, showed it to have the following composition:—

| | |
|---|---|
| Nickel | 75·50 |
| Cobalt | none. |
| Iron | 22·02 |
| Copper | 1·20 |
| Insoluble siliceous matter | 1·16 |
| | 99·88 |

Deducting the insoluble siliceous matter, and recalculating the remaining constituents for one hundred parts, we obtain, as representing the composition of the mineral:—

| | |
|---|---|
| Nickel | 76·48 |
| Iron | 22·30 |
| Copper | 1·22 |
| | 100·00 |

There are only two instances on record of a mineral similar to that above described having been met with. One of these being the nickeliferous iron called "awaruite," referred to by W. Skey (Trans. N. Zeal. Inst., vol. 18, p. 401, 1885) as having been found, associated with gold, platinum, cassiterite, chromite, and magnetite, in the drift of the Gorge river, a stream flowing into Awarua Bay, on the west coast of the South Island of New Zealand; and the other, the iron-nickel alloy described by A. Sella (Compt. Rend., vol. 112, p. 171, 1891) as occurring in the auriferous sands of the Elvo, a mountain-stream, near Biella, Piedmont, Italy.

As tending to facilitate a comparison of these three, apparently closely related, minerals with each other, their analyses are here given in a tabular form,—(1) being the analysis of the nickeliferous iron "awaruite"; (2) that of the iron-nickel alloy from the Elvo, Piedmont; and (3) the analysis, after deducting some insoluble siliceous matter and recalculating the remaining constituents for one hundred parts, of the iron-nickel alloy from the Fraser river, province of British Columbia.

| | G | Fe | Ni | Co | Cu | S | $SiO_2$ | | |
|---|---|---|---|---|---|---|---|---|---|
| (1) | 8·1 | 31·02 | 67·63 | 0·70 | .. | 0·22 | 0·43 | = | 100·0 |
| (2) | 7·8 | 26·60 | 75·20* | | .. | .. | .. | = | 101·8 |
| (3) | 8·215 | 22·30 | 76·48 | .. | 1·22 | .. | .. | = | 100·0 |

The writer would suggest that this mineral be named "souesite," after Mr. F. Soues—to whom he is indebted for the sample sent for identification—to distinguish this find from that of other naturally occurring iron-nickel alloys.

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* Nickel, with some cobalt.

## ART. XXXIII.—*On the Absence of Helium from Carnotite;*
### by E. P. ADAMS.

THE experiments of Sir William Ramsay and Soddy on the formation of helium from the radium emanation account very readily for the well-known fact that the minerals which contain helium in appreciable quantity contain as well one or more of the radio-active elements. It might therefore be expected that all radio-active minerals should contain helium.

I have recently been testing various specimens of carnotite to determine whether or not helium is present in them. Carnotite promises to become an important source of radium; certain specimens have been found which have a radio-activity 1·6 times that of metallic uranium, although it appears to be difficult to obtain large quantities of mineral of such high activity. On heating in vacuo several grams of this carnotite, considerable quantities of carbon dioxide and water were driven off, and when these were absorbed by caustic potash and phosphorus pentoxide respectively, only the nitrogen spectrum could be observed when an electric discharge was sent through a vacuum tube connected to the pump; no difficulty was found in obtaining the helium spectrum when only a tenth as much pitchblende, monazite sand, or thorianite* was used.

The quantity of gas which was obtained from this amount of carnotite was so small that it was thought worth while to work with a larger quantity of the mineral. For this purpose, 300 grams of carnotite of activity 0·8 times metallic uranium was heated at a red heat in vacuo for three hours, and after absorbing the carbon dioxide by caustic potash, about $10^{cc}$ of a gas remained. On sparking this, after adding oxygen, in order to absorb the nitrogen present, a rapid decrease in volume took place, and when finally the excess of oxygen was absorbed by means of phosphorus, only about $0{\cdot}1^{cc}$ of a gas remained. This when introduced into a spectrum tube showed the characteristic red spectrum of argon. It was observed that the greater part of the gas, aside from the carbon dioxide, was given off on the first gentle heating, and it is therefore probable that the argon was associated with the air held in the powdered mineral, which was completely driven off only on heating it.

It therefore appears that if helium is contained in carnotite at all, it exists in far smaller amount than would be expected from the quantity of radium present. But it is probable that this absence of helium may be explained by the physical properties of the mineral. Carnotite is a very fine powder which is usually found disseminated through sandstone. Now even the most compact specimens of this sandstone containing carnotite are exceedingly permeable to gases. This was shown by closing one end of a glass tube with a piece of the mineral about $2^{cm}$ in thickness, and filling it with illuminating gas over water. In a few minutes the water rose a distance of $6–7^{cm}$ in the tube. If we then assume helium to be formed in this mineral by the disintegration of the radium, it appears reasonable to suppose that it rapidly diffuses away. The minerals that contain helium are known to be massive, impervious substances, which are therefore able to retain the helium formed in them.

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* The recently discovered mineral from Ceylon, containing about 75 per cent of thorium, kindly supplied by Dr. George F. Kunz for this purpose.

This explanation of the absence of helium from carnotite seems to be supported by the views of Travers* on the state in which helium exists in minerals. According to him, the helium is present in the minerals in a state of supersaturated solid solution; the minerals being impermeable to the gas at ordinary temperatures, the velocity with which equilibrium is established between the helium in solution and the helium in the gaseous phase is very small, but increases rapidly with rise of temperature. In the case of carnotite, however, the mineral is permeable to the gas even at ordinary temperatures, and therefore we could not expect to find any appreciable amount of helium in this mineral.

Princeton University, Physical Laboratory.

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* Nature, Jan. 12, 1905.

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *Properties of Methane.*—In preparing pure "marsh gas," **MOISSAN** has made use of crystallized aluminium carbide made by heating aluminium with carbon in the electric furnace, then dissolving the excess of aluminium by treatment with hydrochloric acid at 0°, washing with ice-water, dry alcohol and ether, and drying in a vacuum. The aluminium carbide, thus purified, was allowed to act upon water at ordinary temperature in order to produce the methane gas. The gas was then liquefied and solidified, and from the solid product pure gas was obtained for experimental purposes. Eudiometric analysis, by explosion with oxygen, and subsequent absorption of carbon dioxide, gave results agreeing very closely with theory. The density, by direct weighing in comparison with air, was found to be ·5540 and ·5554 as the results of two determinations, which agree very closely with the theoretical density, and are a little lower than that previously found by Thomson and by Schlœsing (·558). When methane was brought into a tube surrounded with liquid air, it solidified at first in a transparent form, like glass; but after a few moments it suddenly crystallized in white needles. It was found to melt at −184° and to boil at −164°. It was found that methane always has a mild, slightly alliaceous odor, which cannot be attributed to impurities. Experiments showed that solid methane is attacked by liquid fluorine at −187° with explosive violence, similar to the action of solid fluorine upon liquid hydrogen. This is another case, therefore, where chemical affinity persists at very low temperatures.—*Comptes Rendus*, cxl, 407. H. L. W.

2. *Silicide of Carbon in the Cañon Diablo Meteorite.*—The fact that **MOISSAN** has found the substance commonly called carborundum in the residue obtained by dissolving 53 kg. of this meteorite has already been noticed in this Journal. The first announcement of this discovery was perhaps not entirely convincing, as it was based merely upon finding crystals exactly resembling silicide of carbon. Further examination has enabled Moissan to show, after separating the minute crystals by means of a heavy solution, that they possess the physical and chemical properties of the compound, and also that they are composed of silicon and carbon. There is now no doubt, therefore, that this interesting compound, previously known only as a product of the electric furnace, actually occurs in nature.—*Comptes Rendus*, cxl, 405. H. L. W.

3. *A New Process for Detecting Ammonia in Water.*—**TRILLOT** and **TURCHET** take 20 or 30$^{ccm}$ of the water to be tested in a test-tube, then add three drops of a ten per cent solution of potassium iodide and two drops of a concentrated solution of an alkaline hypochlorite (commercial Javel's solution). When ammonia is

present, a black coloration is immediately produced, due to the formation of nitrogen iodide. In doubtful cases, where iodine may be set free, a slight excess of the hypochlorite is added in order to dissolve the iodine. The color is sufficiently stable to allow of calorimetric comparison with known amounts of ammonium chloride solution. The authors claim that foreign substances interfere with this reaction less than with Nessler's test, and that other nitrogenous substances do not yield the same reaction.—*Comptes Rendus*, cxl, 374. H. L. W.

4. *Radio-tellurium.*—Marckwald has worked up the crude tellurium obtained from about 15 tons of pitchblende. By dissolving the material and precipitating with sulphur dioxide, about 16 g. of a mixture of selenium, tellurium and radio-tellurium were obtained. Upon oxidizing this with nitric acid, evaporating to dryness and warming with solution of ammonia, a residue weighing about 3 mg. was obtained, which apparently contained practically all of the radio-active material, and possessed "enormous" activity. It is Marckwald's opinion that his radio-tellurium is a distinct substance, not identical with polonium.—*Berichte*, xxxviii, 391. H. L. W.

5. *Conversations on Chemistry, Part I, General Chemistry;* by W. Ostwald. Authorized Translation, by Elizabeth Catherine Ramsay. 12mo, pp. 250. New York, 1905, John Wiley & Sons.—The eminent author was led to write this work, for one reason, on account of the benefit that he derived from using a book of similar character, Stöckhardt's "Schule der Chemie," as his first text-book of chemistry. As another reason, he hopes to overcome the tendency to onesidedness due to the great attention paid to organic chemistry at the present time in Germany, by presenting a treatise on general and physical chemistry, since these may be regarded as the foundation for all real chemical education.

The form of dialogue between master and pupil has been adopted, because it appeared to occupy no more space than ordinary description, while the impression made is much more "penetrating and lively." This is going back to a form of text-book considerably used by our grandparents, but, while we may frequently smile at the almost superhuman aptitude of the pupil in asking the proper questions and in making appropriate comments, the impression gained by an examination of this little book is that it is a most excellent and valuable one.

The book under consideration, which is the first part of a series, deals only with common and simple chemical and physical phenomena. No attempt is made here to introduce any chemical theories, but many points of physics are very clearly explained. The experiments presented are very satisfactory ones. The translator has done good work, and few traces of the German idiom are evident; indeed, there is sometimes doubt in regard to the original language used to express youthful astonishment, as, for example, where the pupil exclaims, "Oh, how ripping," upon observing a striking experiment. H. L. W.

6. *Text-book of Organic Chemistry;* by HENRY LEFFMANN, A.M., M.D. and CHAS. H. LAWALL, Ph.D. Pp. 231. Philadelphia, 1904. (P. Blakiston's Son & Co.)—The work is obviously intended for the use of students of medicine and pharmacy. Throughout the book structural formulas are given, even for such complicated compounds as the purine bodies, cocaine, piperine, camphene, salicin and lecithin. But nowhere is there the slightest suggestion that an accepted structural formula, simple or complicated, is the result of a study of reactions. Asymmetric carbon is referred to and stereochemical formulas printed, but the reason given for the latter is that "as molecules occupy space it is desirable to formulate them on a three-dimensional system." Such treatment is calculated to give an entirely wrong idea of the subject, even though the authors have shown in the main good judgment in selecting the compounds to be treated and have given, usually though not always, the structures commonly accepted by chemists. A student acquires some useful information by studying about the occurrence and physical properties of organic compounds, he learns more by studying those reactions from which are drawn conclusions as to the structure of typical compounds; when he has the elementary knowledge he may even learn something about the behavior of complicated compounds by looking at the accepted structural formulas, but such formulas are confusing and meaningless to one who has not acquired the elementary knowledge. W. J. C.

7. *Electric Inertia.*—Sir Oliver Lodge, in an address before the Institution of Electrical Engineers 1903, calculates the inertia which a small sphere charged with a quantity $e$ of electricity and moving with a velocity $u$ has in virtue of its charge. S. H. BURBURY shows that the magnetic force assumed by Lodge to arise in space from the motion of the sphere is exact if $u$ is supposed to be constant, and also $e$ the charge on the sphere. It is not, however, exact if $u$ or $e$ vary.

Burbury also asks whether it would not be safer to apply other limits of integration than those employed by Lodge. The paper is a keen criticism of the generalities of the theory of electric inertia.—*Phil. Mag.*, Feb., 1905, p. 243–250. J. T.

8. *Double Refractions.*—FERDINAND BRAUN shows various methods by means of which artificial double refraction can be produced. A thin bundle of glass wool threads made into a layer $1^{mm}$ thick shows changes in light under crossed nicols in a polarization microscope; the phenomena can be controlled by immersing the bundle in various oils. The author describes also a method of making stratified dielectrics, which consists in covering glass plates with collodion films, alternating with films of aloe resin (the collodion films are dipped in the resin). Thirty such plates show the Iceland spar cross, and eighty, the ring. Gelatine plates soaked in water until soft, immersed in methyl-alcohol, and built up in a symmetrical orientation, give beautiful images, such as are produced by biaxial crystals. The

author found that similar preparations had been made by earlier observers, especially Nörremberg, and Bertin. Braun extends their work and shows that one of his preparations 2·8$^{mm}$ thick gave rings equal to those produced by a plate of apatite half as thick; or a plate of calcite, 0·1$^{mm}$ thick.—*Ann. der Physik.*, No. 2, 1905, pp. 278–281. J. T.

9. *Emission Spectra of the Metals in an Electric Oven.* — Spectroscopic observations conducted with the electric arc and spark are conditioned to a great degree by electrical phenomena which are difficult to isolate from the mere effect of heat. A. S. King has developed an electric oven similar to one used by Liveing and Dewar, in order to excite emission spectra only through heat. The forms of oven are described at length. The vapors of the metals emitting spectra are formed close to the hot carbon electrodes in these ovens. A resistance oven is also described in which the heat developed by the white-hot resistance excites the emission spectra. Many interesting results were obtained which are summed up as follows :

1. The oven affords emission spectra which in intensity differ widely from those obtained in the electric arc.

2. The method is especially suited for the observation of band spectra.

3. The changes in the series spectra of caesium show that the glowing vapor follows the radiation law of solid bodies.

4. Comparison of series lines in arc and spark spectra of different elements shows that changed electrical conditions can work in the same way as changed temperature conditions.

5. The calcium spectrum in the oven shows a particular relationship of the lines H and K which appear weakly only at the highest temperature. The *g*-line shows an unsymmetrical broadening of the reversal so that it appears to be displaced. The vapor of the oven shows a much greater absorption power for *g* than for the other lines of the spectrum ; this line varies with the temperature.

6. The homologous pairs in the spectrum of Ca, Sr, Ba, with like magnetic types, are relatively much weaker in the oven than in the arc.

7. The oven spectrum gives new bands in the spectra of Ca, Sr, Ba, and Cu. In the green-band group of Ba, there is an apparent displacement of the position of maximum intensity from band to band.

8. The relative intensities of the Cu-lines of the oven approximate to those in a weak arc; the absence of ultra-violet pairs indicates temperature as the source of the radiation.

9. In many cases only a trace of a substance is sufficient to evoke characteristic lines.

10. It is shown that ionized steam, which arises from the arc but is separated from it, gives the arc spectrum even when it lies outside the path of the current.

11. Water vapor in the oven heightens the intensity of metal lines.—*Ann. der Physik*, No. 2, pp. 360, 381. J. T.

10. *The Dynamics of Particles and of Rigid, Elastic, and Fluid Bodies;* by A. G. WEBSTER. Pp. xii+588. Leipzig, 1904. (B. G. Teubner.)—This book is a welcome addition to the long list of text-books on mechanics. The gap between the elementary treatises and the classics of the science is wide and difficult to fill. The mere extent of the field to be covered makes the tasks of compression and selection as important as they are difficult. And at the same time the voluminous literature in each separate department makes a single-volume introductory work giving adequate treatment of the methods (necessarily at the expense of many of the applications) very highly desirable. It is this task that Professor Webster has set himself, and, in the opinion of the writer, very successfully performed.

The field covered is sufficiently indicated in the title. Kinematics is not treated as a separate subject, but is taken up as introductory to each subdivision of dynamics in order. The chapters on the general principles and methods of advanced dynamics are especially to be commended. Students of physics are too often insufficiently acquainted with such matters as generalized coordinates, the calculus of variations, Hamilton's principle, etc.; or if at all it is an academic and not a working knowledge which they possess. For all such the above-mentioned chapters should furnish a valuable guide. The section on rigid dynamics might possibly be criticized as being disproportionately full in the treatment of gyroscopic motion: a fault, if it be a fault, both to be expected and condoned in an author whose original contributions to this subject are so well known. The general theory of the potential function forms the introduction to the section on the dynamics of deformable bodies. This chapter follows very closely the presentation of the same subject in the author's well-known "Theory of Electricity and Magnetism." The remaining chapters of this section,—those on elasticity and hydrodynamics,—are, relatively to their importance, the shortest in the book. They form, however, an excellent introduction to the very extensive literature of these topics.

Typographically and in the matter of illustrations the book is unusually excellent. It appears as the eleventh in the Teubner collection of text-books of the mathematical sciences. L. P. W.

11. *Experimentelle Untersuchung von Gasen;* by M. W. TRAVERS. German translation by T. ESTREICHER. Pp. xii+372. Braunschweig, 1904 (Friedrich Vieweg und Sohn).—This German edition of Professor Travers' invaluable "Experimental Study of Gases" is not a mere translation, but presents considerable matter that is not contained in the English edition of 1902, in addition to being largely rewritten. The book is so well known that it is only necessary here to point out some of the additions which appear in this edition. The chapters on the liquefaction

of gases and on the handling of the same contains much new matter, especially with reference to the liquefaction of hydrogen and the fractional distillation of gas mixtures at low temperatures. All the very recent determinations of the physical constants of the rare gases of the argon group, as well as the new methods used in their measurement, are included. An entire new chapter has been added by the translator on the specific and latent heats of gases, which contains much valuable information both as to methods and results. These constitute the main additions.

As a whole, this German edition can be said to add to the value of a work already indispensable to the worker in gas analysis or low temperature research. L. P. W.

12. *The Dynamical Theory of Gases;* by J. H. JEANS. Pp. viii, 352. Cambridge, 1904. (University Press.)—In the first five chapters of this book is given the theory of the distribution of velocities and of the partition of energy in conservative systems. Two methods of deriving the law of distribution of velocities are given: the classical method of Maxwell and Boltzmann, and a method devised by the author which is not unlike that of Gibbs (Elementary Principles in Statistical Mechanics). Then follow two chapters developing the physical properties of gases as predicated by this theory and the comparisons with experiment. The unsatisfactory result of this comparison, especially in the case of the ratio of the specific heats, is due to the fact that the theory assumes that molecules form conservative systems. This leads to the theory of a non-conservative gas which is treated in the next three chapters. Here for the first time in the book is introduced an hypothesis as to the structure of the molecule. The assumption is made (supported by the evidence of spectroscopy) that the ultimate components of the gas possess a number of isochronous free vibrations. With the aid of this assumption the complete theory is worked out, and the agreement with experiment is shown to be of a very satisfactory nature. Next come six chapters on the various free path phenomena. The book concludes with applications of the theory to planetary atmospheres, molecular aggregation and dissociation, and the calculation of the size of molecules. In the appendices are given tables to aid in the evaluation of the exponential integrals of common occurrence in the kinetic theory.

Altogether this is the most satisfactory treatise on the subject that the writer knows. It is particularly excellent in its treatment of the historic difficulties connected with the question of the partition of energy. The treatment of the non-conservative gas is very original and suggestive. The orderly perspicuous development, the excellent historical perspective, the clear separation of assumption and fact, and the unusual attention paid to the quantitative numerical side of the subject, all contribute to make this one of the notable books of the year. L. P. W.

13. *Optical Pyrometry.*—A paper by C. W. WAIDNER and G. K. BURGESS in the second number of the Bulletin of the Bureau of Standards (see also p. 91, Jan., 1905) gives a thorough discussion of the subject of optical photometry, both as regards theory and methods. The experimental comparison of the various types of optical pyrometers is particularly thorough and valuable. The authors conclude, on the basis of their experiments, that the several laws of radiation are in quite satisfactory agreement at the highest attainable temperatures and thus serve to define the same scale of temperatures. For example, they state that "it would seem that the radiation laws are still in agreement at the temperature of the arc. Our measurements have given as the black body temperature of the hottest part of the positive crater 3690°, 3680°, and 3720° absolute, as determined with the Holborn-Kurlbaum, Wanner, and Le Chatelier pyrometers, based on the extrapolation of Wien's law. Féry gets for this temperature 3760° by a method based on Stefan's law."

## II. GEOLOGY AND MINERALOGY.

1. *Cambrian Brachiopoda with Descriptions of New Genera and Species;* by CHARLES D. WALCOTT. Proc. U. S. National Museum, xxviii, 1905, pp. 227–337.—This is the sixth paper of the preliminary studies for the monograph on the Cambrian Brachiopoda, to be published by the U. S. Geological Survey. In it are described 106 new species, 50 old species, 8 old genera, and the following new genera or subgenera: *Otusia* (type *Orthis sandbergi* Winchell), *Nisusia* (type *Orthis festinata* Billings), *Jamesella* (type *Orthis perpasta* Pompeckj), *Eostrophomena* (type *E. elegantula* new), *Orusia* (type *Orthis lenticularis* Wahlenberg), *Finkelnburgia* (type *F. finkelnburgi* new), *Loperia* (type *L. dougaldensis* new), *Swantonia* (type *Camarella antiquata* Billings), *Rustella* (type *R. edsoni* new), *Curticia* (type *C. elegantula* new), *Quebecia* (type *Obolella circe* Billings), and *Schuchertina* (type *S. cambria* new).

As the generic name *Iphidea* Billings, 1872, was preoccupied by Boyle, 1865, Dr. Walcott here changes the name to *Iphidella*. However, as two other generic names have been proposed for species referred by Walcott to *Iphidella* we are obliged under the rules of nomenclature to replace his by one of these names. The earliest one is Meek's *Micromitra* (type *Iphidea* (?) *sculptilis*), or Beecher's *Paterina* (type *Obolus labradorica*). As *I. sculptilis* has an ornamental surface, it may be well to retain *Micromitra* in a subgeneric sense, in which case we are forced to adopt *Paterina* for the unadorned forms to replace the preoccupied name *Iphidea* Billings.

From the six papers thus far issued, it is evident that Dr. Walcott's monograph is not only to be a monumental volume, but that students of brachiopods will have a firm foundation on which phylogenies and a final classification of these organisms can be built. C. S.

2. *Occurrence of Mastodon humboldtii in Northern Mexico.*—A small collection of Mastodon material, from near the line of the Chihuahua al Pacifico R. R., was presented to the Yale University Museum in 1902, by Mr. CHARLES SHELDON (Yale 1890). The remains include part of an upper tusk and fragments of a tooth from Guerrero, near Concepcion, in the state of Chihuahua, Mexico; also the head of a femur, which was found about sixty miles from Chihuahua. The tooth may be identified with the third upper molar of *Mastodon humboldtii* Cuv., as the cross-crests show the peculiar "double-trefoil" pattern characteristic of that species, and otherwise agree closely with Prof. Cope's definition of *Mastodon* (=*Dibelodon*) *humboldtii* (Fourth Annual Report, Geol. Surv. Texas). This identification is of considerable interest, inasmuch as Prof. Cope stated (*loc. cit.*) that the supposed occurrence of the species in Mexico was based on a misapprehension, the specimen from Mexico described as *M. humboldtii* by Von Meyer (Palaeontographica, 1867) being subsequently arranged by Cope under the new species *Dibelodon tropicus*.

G. F. EATON.

3. *Petrography and Geology of the Igneous Rocks of the Highwood Mts., Montana*; by L. V. PIRSSON. Bull. 237, U. S. Geol. Surv., 1905, 208 pp., 7 pls.—The Highwood Mountains form a group of much eroded volcanoes situated on the great plains of Montana within the great bend on the Missouri River. They present stocks of granular rocks filling the old conduits, which are surrounded by a vast network of radial dikes. There are some intruded sheets and masses of extrusive flows, breccias and tuffs, remnants of the former cones. On the southeast there is an interesting region of intruded laccoliths which affords examples of rock differentiation in place.

The igneous rocks composing these varied masses are of alkalic types, mostly basic in character with a prevailing dominance of potash in the alkalies. They afford a number of interesting and novel kinds, some of which, such as shonkinite and missourite, have been previously described by the author in conjunction with Mr. W. H. WEED. In this bulletin the geology of all these occurrences is described and the petrography of the different rocks given in full detail with chemical analyses. The new quantitative system of classification is used, giving an opportumity of testing its practical working. In conclusion, the bearing of the facts observed on the origin and differentiation of igneous rocks is treated.

4. *Red Beryl from Utah*; by W. F. HILLEBRAND. (Communicated.)—From Mr. Maynard Bixby of Salt Lake City, there have recently been received three crystals of beryl which because of their color—a rich raspberry-red—seem to merit notice. The specimens show single crystals of short prismatic or tabular shape, 3 millimeters in height and up to 7 millimeters across the basal plane, implanted on imperfect topaz crystals. According to Mr. W. T. Schaller, the only other forms are those of prisms of

the first and second order, the habit being the usual one for beryl, and the specific gravity is 2·65. The color is presumably due to manganese, of which the crystals contain a very appreciable amount. Approximate chemical determinations leave no doubt as to the identity of the species. The locality of occurrence is that make known by the discovery of bixbyite, about 35 miles southwest from Simpson Springs, Utah, in the Dugway Range. The matrix is rhyolite, and the chief associates, according to Mr. Bixby, are topaz, bixbyite and altered garnets.

5. *The Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada;* by ALFRED ERNEST BARLOW. 236 pp., with 24 plates and five geological maps. From vol. xiv of the Annual Report of the Geological Survey of Canada. Part H.—The importance of the Sudbury mines will be appreciated when it is stated that they now give Canada the position of the largest producer of nickel in the world. This report by Mr. Barlow is an admirable presentation of the whole subject, describing the geological relations and composition of the deposits, discussing their origin and also giving an account of the methods of mining and metallurgical processes. A summary is also added of the occurrence of nickel in other parts of the world, with particular reference to the Scandinavian deposits which in many respects are strikingly similar to those of Canada.

The nickel- and copper-bearing ore bodies consist essentially of pyrrhotite, by far the predominant constituent, chalcopyrite in much smaller amount and also pyrite. The nickel, however, is almost entirely confined to the species pentlandite, which is in general very uniformly distributed throughout the whole mass. Both the pyrrhotite and pyrite carry nickel in small amount, but it is not certain that it really belongs to the composition of these minerals, some authorities referring it here also to admixed pentlandite. Besides the species mentioned, the following nickel minerals also occur in limited amount: millerite, polydymite, niccolite, gersdorffite and marcasite. Other associated species are the following: morenosite, annabergite, sperrylite, danaite, smaltite, galena, chalcocite, bornite, magnetite, cassiterite, native copper, native gold, graphite, cubanite and some others.

The deposits occur in connection with certain eruptive rocks. These are discussed by the author under two divisions:

(1) A basic portion:—Including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel- and copper-bearing sulphides are immediately associated.

(2) An acidic portion:—Comprising large areas of rock of granitic type, with well-marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and feldspar, known as granophyre or micropegmatite, having suggested the name "micropegmatite," by which this rock is now generally known.

The origin of the ore deposits is discussed in detail and the author states his belief that the Sudbury deposits, like those of

Norway described by Vogt, are of igneous origin, being the direct product of the differentiation of a basic igneous magma modified to some extent by certain secondary processes.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Studies in General Physiology;* by JACQUES LOEB. The Decennial Publications of the University of Chicago, 2 vols., 782 pp. University of Chicago Press, 1905.—These studies include a series of papers collected from Professor Loeb's important contributions to general physiology during the past fifteen years. The range of topics selected is broad; yet, in the words of the author, "a single leading idea permeates all the papers of this collection, namely, that it is possible to get the life-phenomena under our control, and that such control and nothing else is the aim of biology." The present form of presentation will be especially welcome to many readers, since most of the papers are here given in English translation for the first time. In this collection will be found the well-known researches of Loeb on the heliotropism of animals and on heteromorphosis, various papers in the field of physiological morphology—the study of the connection between chemical changes and the process of organization in living matter; while most of one volume is devoted to investigations involving the application of the modern physical chemistry to the solution of biological problems. Prominent among these are studies on the physiological rôle of ions, and the splendid observations on artificial parthenogenesis. The reader may, at times, be inclined to hesitate in accepting the generalizations of the author; but one must admire the enthusiasm and untiring energy of the investigator, the wealth of important observations presented, and the originality of treatment which fundamental problems receive. Professor Loeb has won an enviable reputation which is well deserved. The University of Chicago is to be congratulated in the publication of these commemorative volumes. L. B. M.

2. *The Birds of North and Middle America;* by ROBERT RIDGWAY. Part III, pp. xx, 801 with 19 plates. Bulletin No. 50 of the U. S. National Museum.—This is the third part of this important work, already noticed in these pages; it includes the species of fifteen families from the Wagtails and Pipits (Motacillidæ) to the Warblers (Sylviidæ). The three volumes already published include some twelve hundred and fifty species and subspecies, that is about two-fifths of all the North and Middle American Birds.

3. *British Museum Catalogue:—A Synonymic Catalogue of Orthoptera;* by W. F. KIRBY. Vol. I, pp. x, 501. London, 1904.—The author, who has recently carried through a re-arrangement of the Orthoptera of the British Museum, has now prepared a complete catalogue of the Order. This first volume contains the species of five families and the remaining three will be included in one, or possibly two, additional volumes. This work will be of great value to all students of Entomology.

THE

# AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. XXXIV.—*On the Physiographic Improbability of Land at the North Pole;* by J. W. SPENCER, A.M., Ph.D.

THE earlier explorers had little to guide them, but they brought back occasional soundings, which seemed to indicate a shallow Arctic basin. The drift wood suggested that it was a more or less open sea, beneath the ice floes, even though its depth might not be great. Some soundings were of unusual depth, but their importance, not being known, was entirely overlooked. The soundings in the Arctic region were insufficient of themselves to suggest their own explanation, before the character of drowned channels was understood. Indeed, while occasional valleys channeling the submerged border of the continent had been noted by Dana, Lindenkohl, Milne-Edwards, Davidson, Issel, the present writer, Upham, and others, the systematic study of these features really dates back only to 1893–4, resulting in the publication of the "Reconstruction of the Antillean Continent."* This has been the pioneer of many subsequent contributions on submarine valleys and drowned plains. The same features have been studied on the western side of Europe by Prof. Edward Hull,† and in the Arctic region and farther south by Prof. F. Nansen.‡ Accordingly the features of submarine valleys channeling the edge of the Continental mass are now pretty well understood, so that we can interpret even the limited amount of data already obtained in the Arctic region and have some reasonable understanding of the phenomena which they indicate.

I was in northern Norway when the Ziegler expedition sailed, and hearing of their expectation of finding Polar land,

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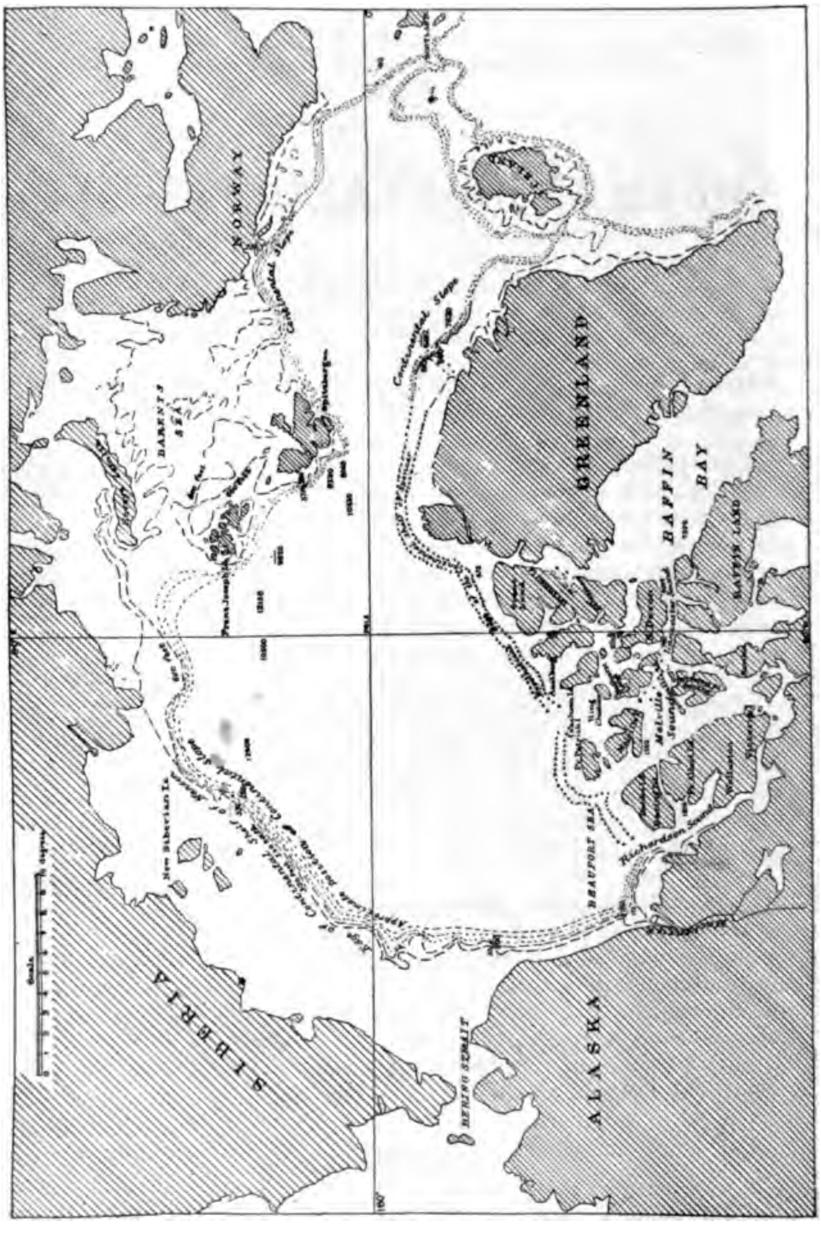
* By the present writer, Bull. Geol. Soc. Am., vol. vi, pp. 103–140, 1894.

† Numerous papers, mostly published in Trans. Victoria Institute, London, 1898–1902.

‡ On Bathymetrical features, Continental Shelves and Oscillations, Christiania, 1904, pp. 232, plates 28.


NORWAY
ICELAND
GREENLAND
BAFFIN BAY
BAFFIN LAND
BARENTS SEA
Spitzbergen
Franz Joseph Land
Continental Slope
New Siberian Is.
Melville Sound
Richardson
BEAUFORT SEA
SIBERIA
BERING STRAIT
ALASKA
Scale

I felt that disappointment was in store for them; for Dr. Nansen's great discovery of a profound Arctic basin, immediately beyond the border of the continental shelf, precluded the probability of finding land between Franz Joseph Land and the Pole, or indeed along this line for a thousand miles beyond, until approaching the embouchure of the Mackenzie River, although to the left of this line the continental shelf north of Greenland, bearing perhaps an island, might extend far polarward. Nansen had found the Polar basin to reach a depth of 12,000 feet or more. This would have to be crossed by any expedition from the European side and here no portable sounding apparatus could be effective until approaching the American shelf beyond the deep basin itself. But had the undertaking been made from Grant Land, soundings to a depth of 3000 feet or less would have surely revealed the rapidly increasing depth of the slope from the continental shelf to the abyss of the basin, out of which no land could be expected to rise. Thus the character of the Polar district would have been discovered, perhaps without reaching to within some hundreds of miles of the Pole, depending upon whether the shelf extends far north of the known land or not. If the Ziegler expedition were for the purpose of adding to our knowledge, it is to me astounding that the route chosen should have been approved of by the advisers, knowing of the deep sea north of Europe, even without such analysis of the subject as has since been published by Nansen, or is here set forth. If the voyage were only one of adventure to reach an icy Pole without any ostensible scientific object, then I give no opinion as to the route taken. These remarks directed to an actual expedition would equally apply to the proposed one of the Duke of Orleans. They are written in the hope that future Polar explorers will take cognizance of the scientific submarine topography, avoiding useless expeditions and devoting their efforts to extending scientific knowledge.

To define the features around the Arctic basin, I should draw an axis from Cape Bathurst, passing close to Bank's Land, Prince Patrick's Land, the Pole, and on to Franz Joseph Land and Novaya Zemlia, thus dividing it into two unequal lobes. The one on the Siberian side is bounded by low lands, with few islands, all of inconsiderable height in front. The confines of the other lobe have bold features in the mountainous islands of Novaya Zemlia, Franz Joseph Land, Spitzbergen, North Greenland, Grinnell Land, Sverdrup's New Land to Prince Patrick's Land and Bank's Land, which have less abrupt features.

In front of the Siberian plains and north of Bering Straits, Dr. Nansen has shown from his own and other soundings that the continental shelf has a breadth of 300 or 350 nautical miles (see map). Its outer margin is at a depth of 300 feet, beyond which is the rapid descent of the continental slope. In front of Spitzbergen, and apparently adjacent to Franz Joseph archipelago, the shelf has a breadth of only about 30 miles. Its border recedes and forms an embayment east of Novaya Zemlia. North of the New Siberian Islands, Nansen found that the submergence of the continental slope increased from about 300 feet to 6000 feet in 30 miles. A similar gradient has been found adjacent to Spitzbergen. Soundings in sufficient numbers have been taken to establish the existence of the broad shelf, with a few others suggesting its border, as for instance, where in proceeding outward the sea suddenly deepens from 300 feet to 700–800 feet. Thus defined, Nansen's map shows a direct line in front of Bering Straits to north of Alaska. Here the continent encroaches upon and greatly contracts the shelf,—an important analytical feature. The shelf appears to be reduced to a breadth of perhaps 40 miles. The Arctic basin does not approach Bering Straits, which is only a shallow lateral trough from the basin itself, but ends in Beaumont Sea, between Prince Patrick's Land and Alaska, where the Mackenzie River, after passing through its own broad embayment or delta, extends to a submarine valley discovered, so far, to a depth of over 1140 feet beneath sea level, thus deeply incising the shelf. In the broad channel between Bank's and Baring Lands and the continent, which (unless it is otherwise named, and the charts do not show it) might appropriately be called Richardson Sound, after its explorer (1848), the submarine valley has a depth of 1836 feet, near the head of a branch fjord, at a point 175 miles within the line of the islands.

Lower down the sound are a number of deep soundings, but they do not reach the bottom in the central axis. Beyond, in McClure's Strait, which separates the eastern side of Bank's Land from Melville Island, the fjord attains a depth of 1362 feet and more, at a point 200 miles within the line of the islands. Here we have found the evidence of deep submarine valleys or fjords entering Beaumont Sea from three different directions, and very much deeper than the submergence of the great continental shelf of the Arctic basin. Further proof is not needed to establish the fact that Beaumont Sea is a broad profound valley leading to the Polar basin, though the depth is not known. Also, that the continental shelf is deeply channelled by the valleys. Now, as we have learned from the analysis of the submarine valleys or fjords off Norway and both coasts of America, the border of the continental shelves does not usually exceed a distance of more than from 40 to 100 miles beyond the outer line of the land or islands. Off

Spain and Portugal the shelf is reduced to 6–20 miles. While the Norwegian channel is much longer, yet it hardly forms an exception to the rule, for the edge of the continental shelf, even here, is within the line of the land between Scotland and Norway. Even now we have sufficient data to show that the edge of the lower platform at a depth of 1200 feet (like in Barentz Sea) does not exceed a distance of 60 to 100 miles from land off East Greenland and in Baffin Bay. From my familiarity with the study of continental shelves, the margin of that beyond even the lower part of Prince Patrick's Land should not be expected to extend more than a hundred miles, if indeed so much, with such a deep channel extending far within the line of the islands. Neither the Mecham nor the McClintock expeditions found land beyond the northern side of Prince Patrick's Land. These fjords are in the western side of the archipelago. Four hundred miles farther east (south of the western end of North Devon) in the head of Lancaster Sound we find another fjord with a depth of 780 feet deepening in 150 miles to over 4000 feet at a point 50 miles within the line of the islands, while other soundings show the shelf to attain a breadth of only a few miles in this part of Baffin Bay adjacent to the deep fjord, but elsewhere it reaches to 100 miles. About 160 miles north of Lancaster Sound, in Cardigan Strait, on the Arctic side of the *col* between North Devon and North Kent, the depth of the fjord exceeds 2400 feet. This point is situated about 250 miles within the line of Sverdrup's New Land, showing that here is another deep channel trending to the Arctic basin. Now with even the few soundings before us (and there are many more not cited here) the fjord-like character of the archipelago cannot be questioned. It is a dissected plateau region (much of which is now 2000 or 3000 feet high, subsequently submerged in part—a region fashioned by atmospheric agents whether now above or below sea level. As the depths mentioned are far within the land line, and in the case of one sound a depth of over 4000 feet occurs even 50 miles within the land line, there is every reason to expect similar depths nearer the mouths of the other fjords mentioned. Where the submarine valleys have attained considerable depths within the land line the shelf should be relatively narrow; and judging from the position of Sogne fjord (nearly 4000 feet deep) I should not expect to find the breadth of the shelf exceeding 50 miles in front of Sverdrup's New Land, as much of the region is a weatherworn plateau. One sounding north of Grant Land strengthens this view. At about 30 miles off the land the sounding shows 432 feet, somewhat in excess of the submergence of the Arctic continental shelf wherever known off the Siberian coast. It would seem that the edge is being approached. Nansen has pointed out the remarkable uniformity of the shelf in the Polar basin. Continental shelves are characteristically narrower in front of bold highlands than where they fringe low plains as on the other side of the Polar basin. Apparently the question of the formation of the continental shelf in one part of the Arctic cannot be separated from the rest of it. No land was discerned beyond Prince Patrick's or from Sverdrup's New Land.

From the absence of land for a hundred miles, from the occurrence of the sea depth at 432 feet thirty miles from land, and from the characteristic of narrow shelves in front of high lands, I suspect that Commander Peary passed the edge of the shelf and was perhaps over the deep basin, as he would have been in front of Spitzbergen. From this consideration and from the feature of limitation of the continental shelves being indicated by the presence of deep fjords as found among the islands of the archipelago, and from the characteristics of the platforms in front of high lands, I am inclined to place a theoretical limit of from 50 to 100 miles as the breadth of the shelf in front of the known islands, without the expectation of finding any great islands farther north. If this approximation, based upon physiographic information of no mean value, be correct, there would still remain a distance of 300 or 350 nautical miles between the edge of the shelf north of Grant Land and the Pole, beneath the ice of which obtains the deep basin. The edge of the shelf, indicating the limit of the insular extension of continental lands, wherever found, precludes the probability of land beyond, rising out of a deep sea basin.

Having found a working hypothesis from the physiographic features, other phenomena in support of the hypothesis based on the submarine topography have been mentioned by Dr. Nansen. Along the course of the Fram, at depths of more than 800–900 meters, colder heavy bottom water was found, above that affected by subterranean heat, but beneath the overlying stratum of warmer water. It must have cooled down somewhere in the unknown Arctic basin, in contact with the cold surface water; and this place of wide extent is somewhere far from the course of the Fram, occupying probably the greater part of the still unknown Polar region. Similar phenomena exist in the Norwegian Sea, where, however, the center of cold has been found. The drift of the ice under the coast of Greenland is much greater than where the ice belt is broader in the Polar sea. These additional phenomena further preclude the idea of Polar land.

I have not touched upon the question of possible land north of Bering Straits. The position is much farther from the Pole than that of the locations considered. Nor has the question of tides been referred to. This last has been ingeniously discussed by Dr. R. A. Harris.* According to him, the currents set eastward and westward from Bering Straits, which he thinks is caused by land to the north. The tides coming from the east of Greenland (rising two feet) recur near Bennett Island, north of the New Siberian, with the same range. The drift of the Jeannette was accelerated on approaching this locality as if a broad strait were situated here. On the coast of Alaska, the tide is reduced to a few inches, caused, Dr. Harris thinks, by the interference of a large land area. Now Bennett Island is more than 100 miles within the border of the continental shelf. Nansen crossed its edge 200 miles northwest of this point, so there is room for an island of considerable size without the shelf protruding beyond its general outline. Although the outline of the shelf, north of Bering Straits, seems to have been approximated, there may be in front of it a secondary platform, on which remnants of a higher one, surmounted by land, occur with characteristics resembling rather the New Siberian archipelago than Spitzbergen, although this last mass partly rises above a lower platform, as would be the case with part of the hypothetical islands north of Bering Straits. It is only on an extension of the continental shelf that the occurrence of land could be expected, and any great extension of it would disturb the symmetry of its outline, a point which should not be overlooked. If the phenomena described by Dr. Harris really demand a great land mass, physiographically there is no reason why there should not be even a nearly continuous chain of islands from near Bennett Island extending towards Prince Patrick's Land, though it could not occur in front of Beaumont Sea. But I find no ground here for extending land nearer than ten degrees of the Pole. Islands would satisfy the tidal currents off Alaska according to Dr. Harris, though it might not explain the tide rising two feet to Bennett Island. My conclusions agree with those of Sir Clement Markham, quoted by Dr. Harris:—who "does not believe in any land near the Pole, but believes there is land probably in the form of large islands between Prince Patrick's Land and the New Siberian Islands." I should limit their occurrence to a line directly connecting these islands, with no important additions, to the American archipelago, a theory suggested by the enclosed fjords. An island may exist near Simpson cove as suggested by Dr. Harris, perhaps constituting the end of a chain from Bennett Island skirting the edge of the continental shelf.

If I were permitted to plan out an expedition for the purpose of adding to our knowledge of Arctic physiography, it would be somewhat on the following lines, so far as physical conditions would permit. Two expeditions have reached Prince Patrick's Land. Another might enter by Bering Straits, skirt the ice and make close soundings in Beaumont Sea, discover the deeper canyon of Mackenzie River, explore to the bottom Richardson Sound and the channels to Prince Patrick's Land. If the ship could not be drifted past this place, a land and over-ice party with portable sounding apparatus, for depths of 500 fathoms, or if possible a little more, should make the utmost effort to reach a point where the water had either such a depth, or land were found, if the sea continued shallow beyond expectations. A hundred miles have been crossed by Peary; probably so long a journey would not be needed. If the ship could be drifted in the ice north of Prince Patrick's, the sound between this land and Sverdrup's New Land should be explored, for islands or open sea. Else the ship might have to follow the old route through Melville Sound, with an effort to revisit Isachsen Land (one of Sverdrup's New Lands), carrying the ship, or repeating the over-ice sounding expeditions to determine the border of the continental shelf. Such a program should be continued to north of Grant Land, various points of which have been visited, even if the ship could not be worked or drifted in the ice. North of Grant Land, and also Greenland, should be revisited as by Commander Peary, but carrying the sounding apparatus, so that when the edge of the continental shelf shall be reached, the explorer would know when his work was finished and avoid useless adventure. Such an expedition, perhaps requiring several years, should be made to round off Polar explorations. It seems to me to be the only one promising great results, at least of a finishing character. Explorations north of Bering Sea would be farther away, and I have no suggestions to make except to sound well the region traversed, by the ship or sledge party attempting a further voyage.

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* Nat. Geog. Mag., vol. xv, pp. 255–261, 1904.

This little paper is only an application of the study of the deep channels trenching the eastern coastal plains of the continent; which study throws much light upon the subject of the physiography of even the Polar regions. There is also an economic aspect of the question of such submarine physiography, as in the laying of cables, so that they will not swing over the precipices of drowned canyons and consequently collapse. Prof. Davidson has reported ships lost by not being able to drop anchor during storms through being unaware of the adjacent shoal waters, outside of the limits of the drowned channels.

## ART. XXXV. —*Bibliography of Submarine Valleys off North America*; by J. W. SPENCER.

*Papers on the Submarine Valleys indenting the Continental Shelf off the American Coast and in the West Indies;* by J. W. SPENCER.

THE appearance of the "Submarine Great Canyon of the Hudson River" has emphasized the absence of easy reference to the scattered contributions where those interested have not continuously been giving the subject their attention. In this case, it may be expressed in the language of a gentleman, a stranger to the writer, who says that he is "now much interested in this particular subject, but has been unable to get hold of any matter regarding it otherwise than a vague popular sketch here and there which has left him about as much in the dark as though he had read only the title." Some of the papers are not of recent appearance. Others have been published abroad. This condition is perhaps sufficient reason to assemble the list of the papers. The subject is one of equal interest in Europe as here, where there would be a greater difficulty in knowing what had appeared on this side of the Atlantic.

In order to call the attention of the American student to what has been done by Prof. Edward Hull and Prof. Fridtjof Nansen, I have prepared somewhat lengthy summaries of their contributions on this subject, as these are more difficult of access here. The writer's investigations are the slow outgrowth of his studies of the origin of the basins of the Great Lakes, which will not be further referred to here. Otherwise, as bearing on the Atlantic border the investigations began with:

1. "High Continental Elevation preceding the Pleistocene Period;" Bull. Geol. Soc. Am., vol. i, pp. 65–70, 1889; Geol. Mag. Lond., III, vol. vii, 1889. (This contains a description of the submarine valleys of the Gulf of St. Lawrence and of Maine to depths of over 3000 feet. The former is now known to be over 5500 feet.)

2. "Terrestrial Subsidence Southeast of the American Continent" (a preliminary notice of the next paper) with map. Bull. Geol. Soc. Am., vol. v, pp. 19–22, 1893.

3. "Reconstruction of the Antillean Continent" with map. Bull. Geol. Soc. Am., vol. vi, pp. 103–140, 1894–5. (Here is a description of the submarine valleys extending beyond the buried channels of great land rivers, and trenching the continental shelf to abyssmal depths, from Cape Hatteras to the Gulf of Mexico and in the Caribbean Sea. The evidences therefrom indicate great Pliocene and Pleistocene elevations, and the land connection of the two Americas. This is the first constructive paper

on the subject, and together with the discussion of the bearings is the foundation of the subsequent work.) Abstract in Am. Nat., vol. xxviii, pp. 881–884. Also an important "Note on Mr. Kummel's review," concerning the gradient of the valleys. Jour. Geol., vol. iii, pp. 497–498, 1895.

4. "The Yumuri Valley of Cuba—a rock basin." Geol. Mag. Lond., IV, vol. i, pp. 499–502, 1894.

5. "Preliminary Notes on the late Connection and Separation of the Pacific Ocean and Gulf of Mexico," Ib., vol. ii, pp. 306–308, 1895.

6. "Geographical Evolution of Cuba," Bull. Geol. Soc. Am., vol. vii, pp. 67–94, 1896 (with more details of the submarine valleys and their geological relationship, terraces, etc.).

7. "On the Continental Elevation of the Glacial Period," Geol. Mag. Lond., IV, vol. v, pp. 32–38, 1898 ; Abstract B. A. Rept. for 1897, pp. 651–652. (This contains a notice of the recurrence of the submarine valleys, on both sides of the North Atlantic and in the Arctic Sea. It was preliminary to No. 23.)

8. "Geological Canals between the Atlantic and Pacific Oceans." Abstract preliminary to No. 9. Proc. Am. As. Ad. Sc., vol. xliv, pp. 139–140. 1896.

9. "Great Changes of Level in Mexico and the Interoceanic Connections," Bull. Geol. Soc. Am., vol. ix, pp. 13–34, 1898. (Here is shown changes of level complementary to those indicated in the submarine valleys.)

10. "Late Formations and Great Changes of Level in Jamaica." Trans. Can. Inst. Toronto, vol. v, pp. 324–357, 1898. (With further details of the relationship of the submarine valleys to the land features, of the characteristics of the submarine platforms, of land connections, etc.) Abstract in this Journal, IV, vol. vi, pp. 270–272, 1898.

11. "Resemblances between the Declivities of High Plateaus and those of Submarine Antillean Valleys." Trans. Can. Inst. Ib., pp. 359–368. Abstract this Journal, IV, vol. vi, pp. 272–273, 1898. (Showing the gradients of both kinds of valleys by steps, an important supplement to the Antillean paper, No. 3.)

12. "The West Indian Bridge between North and South America," Pop. Sc. Monthly, vol. liii, pp. 10–30, 1898.

13. "Geological Waterways across Central America," Ib., pp. 577–593.

14. "Prof. Hull's 'Submerged Platform of Western Europe.'" Geol. Mag., Lond., IV, vol. vi, pp. 16–18, 1899.

15. "Mr. Huddleston's 'On the Eastern Margin of the North Atlantic Basin.'" Ib., pp, 559–566. (A reply to his criticism of Prof. Hull's work.)

16. "The Windward Islands of the West Indies." Trans. Can. Inst., vol. vii, pp. 351–370, 1901.

17–22. "On the Geological and Physical Development of:— Antigua ; Guadeloup, Anguilla, St. Martin, etc. ; St. Christopher Chain and Saba Banks ; Dominica; with notes on southern

islands, Barbadoes and Trinidad." Six papers in Quar. Jour. Geol. Soc., Lond., vol. lvii (1901), pp. 490–544 and vol. lviii, pp. 341–365. (The local development of the insular shelves, the submarine channels and valleys, and their associated geological and physiographic relationships are considered, while in No. 16 they are further correlated.)

23. "The Submarine Valleys Off the American Coast and in High Latitudes," Bull. Geol. Soc. Am., vol. xiv, pp. 207–226, 1903. (This is an amplification of No. 7 and a delayed continuation of the paper on the Antillean Continent, No. 3.)

24. "The Submarine Great Canyon of the Hudson River," this Journal, IV, vol. xix, pp. 1–15, 1905. (The most perfectly explored of all the American canyons.)

25. "On the Physiographic Improbability of Land at the North Pole," as in this Journal preceding this list. (An application of the study of Submarine valleys to exploration of the unknown Arctic region.)

26. "Prof. Hull's 'Sub-oceanic Terraces and River-Valleys off the Coast of Europe.'" A Review. Am. Geologist, vol. xxxv, 13 pages (in press), 1905.

27. "Dr. Nansen's 'Bathymetrical Features of the North Polar Sea, with a Discussion of the Continental Shelves and the Previous Oscillations of the Shore-Line." A Review. Am. Geologist, vol. xxxv, 15 pages (in press), 1905. In this Dr. Nansen discusses American valleys.

The study of the submarine valleys is in its infancy, and while the work in the above papers somewhat overlaps and embraces many features, these have been considered incidental to working out the submarine channel, valleys, etc., dissecting the submarine border of the continent. These valleys are regarded of atmospheric origin from the facts brought out, therefore they become evidence of great changes of level of land and sea. Some of the consequences of such changes are considered. But only a commencement of the great problem has been inaugurated.

While references have been made to the work of others in the writer's papers, the addition of the following contributions will make a nearly complete list, so far as America is concerned. As to Europe, the references in the papers of Prof. Edward Hull and Dr. Fridtjof Nansen are equally comprehensive.

Prof. J. D. Dana: "The Hudson River Channel;" in all editions of The Manual of Geology (1863–1895).

"Long Island Sound in the Quaternary Era, with observations on the Submarine Hudson River;" this Journal (3), vol. xl, pp. 425–437, 1890. (In all cases the submarine channels are regarded as submerged valleys.)

Prof. A. Lindenkohl: "Geology of the Sea Bottom in the approaches to New York Bay," this Journal (3), vol. xxix, pp. 475–480, 1885.

“Notes on the Submarine Channel of the Hudson River, and other evidences of Postglacial Subsidence of the Middle Atlantic Coast Region. This Journal (3), vol. xli, pp. 489–499, 1891 (in which the channel was differentiated, with the recognition of the continuing canyon to a depth of about 3000 feet).

Prof. George Davidson : “Submarine Valleys of the Pacific Coast of the U. S.” Bull. Cal. Acad. Sc., vol. ii, pp. 265–268, 1887. (Calling attention to the valleys and describing three of them, without discussion of origin.) Others are described in his Pilot of the Pacific Coast, 1889, pp. 35–36, 51–52. (He refers to having later designated them “submerged.”)

“The Submerged Valleys off California (U. S.), and of Lower California (Mexico). Proc. Cal. Acad. Sc. (3), vol. i, pp. 73–103, 1897. (Here the Continental Shelf is considered, 31 submerged valleys are described dissecting it, and the features of the adjacent land are given. Several are traced to 2000 feet, one to 3600, and one to 5000 feet below the surface of the sea.)

Dr. Warren Upham: “Quaternary Changes of Level ;” Geol. Mag. Lond. (3), vol. vii, pp. 492–497, 1890.

“The Fjords and Lake Basins of North America considered as evidence of Preglacial elevation, and depression during the Glacial Period.” Bull. Geol. Soc. Am., vol. i, pp. 563–567, 1890. (He also treats of some foreign examples.)

“Submarine Valleys on Continental Slopes ;” Abstract, Proc. Am. As. Ad. Sc., vol. xli, pp. 171–173, 1892.

“Fjords and Submerged Valleys of Europe ;” Am. Geol., vol. xxii, pp. 101–108, 1898.

Prof. Joseph Le Conte : In Tertiary and Post Tertiary Changes of Atlantic and Pacific Coast,” etc. Bull. Geol. Soc. Am., vol. ii, pp. 323–330, 1890. (Discusses the submerged valleys as such, with their beheading by orogenic movements.)

In “Earth-Crust Movements and their Causes ;” Bull. Geol. Soc. Am., vol. viii, pp. 113–126, 1897. (He discusses the oscillations which favored the excavation of land valleys, and subsequently submerged them.)

Prof. A. C. Lawson : In “The Geology of Carmelo Bay ;” Bull. Univ. Cal. (Geol. Dept.), vol. i, pp. 57–59, 1893, also page 155 (in which he briefly discusses the submarine valleys, believing them to be structural).

Prof. Harold W. Fairbanks : “Oscillations of the Coast of California during the Pliocene and Pleistocene.” Am. Geol., vol. xx, pp. 213–245, 1897. (Discusses the submarine valleys, pp. 228–245, with the conclusion that they are submerged land valleys formed in the early Pleistocene days.)

Mr. W. S. Tangier Smith : “The Submarine Valleys off the California Coast,” Science, vol. xv, pp. 670–672, 1902. (He suggests that some of the submarine valleys were made or opened by subterranean streams.)

Prof. N. S. Shaler : “Evidences as to the Changes of Sea Level.” Bull. Geol. Soc. Am., vol. vi, pp. 141–166, 1895. (Discusses drowned harbors, that of St. Lawrence, etc., subterranean *channels* of Florida, etc.)

## ART. XXXVI.—*On an Interesting Variety of Fetid Calcite and the Cause of its Odor;* by B. J. HARRINGTON.

ABOUT fifty years ago, when Sir W. E. Logan was studying the geology of the Grenville region in Canada, he came upon an interesting variety of calcite in the township of Chatham (lot 10, range xi) which emitted "when rubbed an overpowering odor like that of sulphuretted hydrogen."* In the "Geology of Canada," published in 1863, Dr. T. Sterry Hunt again called attention to what is evidently the same material, as follows: "We may here notice a peculiar variety of fetid carbonate of lime, which forms a large bed in the Laurentian series, in Grenville. It is a very coarse-grained, cleavable, milk-white and apparently pure calcite, which when struck or very lightly scratched, evolves a most powerful and unpleasant odor, recalling somewhat that of phosphuretted hydrogen. It dissolves without residue in dilute acids, and the carbonic acid gas evolved does not affect solutions of lead or silver salts, so that it is difficult to say to what the peculiar smell of this singular rock can be due. It is entirely distinct from the bituminous odor, which is evolved by percussion from a great many of the limestones of the Palæozoic series, or from that produced by striking some siliceous rocks."

Specimens of this interesting calcite have long been in possession of the writer, and it was felt that it should be possible to arrive at some definite conclusion with regard to the cause of the fetid smell. Thin sections were in the first instance studied and showed under the microscope the presence of great numbers of very minute cavities, evidently containing a liquid, as moving bubbles due to the contraction of the liquid could occasionally be seen. These cavities suggested the presence of hydrogen sulphide in a liquid condition or possibly in solution in water. If the gas were present in either condition, it was obvious that it would be liberated either by solution of the calcite in an acid or by pulverizing the mineral; further, that the finer the degree of pulverization the more hydrogen sulphide would escape. This was fully confirmed by experiments made both by the writer and by Mr. Lloyd Lodge, demonstrator in the chemical department. It has been found, moreover, that Hunt's observation with regard to the action of the escaping gas upon solutions of lead or silver salts is erroneous, for in both cases black precipitates are obtained, while in the case of cadmium salts the characteristic yellow precipitate is produced. The inference would appear to be that Hunt worked with the finely pulverized mineral, from which most of the hydrogen sulphide had been liberated, or that the gases were not passed into the solutions of the salts in question for a sufficient length of time.

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* Geological Survey of Canada, Report of Progress, 1853–54–55–56, p. 23.

A specimen of the calcite was found to have a specific gravity of 2·713 and gave on analysis the following percentage composition:

| | |
|---|---|
| Lime | 55·330 |
| Magnesia | 0·540 |
| Ferric oxide | tr |
| Carbon dioxide | 43·925 |
| Sulphur as $H_2S$ | 0·016 |
| Phosphoric anhydride | tr |
| Insoluble matter | 0·026 |
| | 99·837 |

The sulphur was determined by dissolving the mineral in dilute hydrochloric acid, passing the evolved gases into an alkaline solution of cadmium chloride and weighing the precipitate of cadmium sulphide. In the estimation of the phosphoric anhydride the mineral was dissolved in nitro-hydrochloric acid, so that if any phosphorus were present as phosphide its oxidation to orthophosphate might be ensured. As the quantity of insoluble matter was insignificant, the determination was made upon about thirty grams of mineral—hydrochloric acid being the solvent. The filtrate from the insoluble matter was tested for sulphates, but gave no precipitate with barium chloride. In the analysis of another specimen of the calcite Mr. Lodge obtained results very similar to the above, but found a slightly higher percentage of hydrogen sulphide (0·021).

The following figures illustrate the different results obtained in determinations of the hydrogen sulphide according to the coarseness or fineness of the calcite:

| | Lumps. | Powder of medium fineness. | Very fine powder. |
|---|---|---|---|
| $H_2S$ from 29·45 grams of mineral | 0·00471 | 0·00176 | 0·00035 |
| Percentage of $H_2S$ | 0·01600 | 0·00560 | 0·00120 |

The figures show that the fine powder contained less than $\frac{1}{13}$th of the amount present in the unpulverized material, and had the grinding been further prolonged there would no doubt have been a still greater difference.

On grinding a few fragments of the calcite under water in a porcelain mortar and filtering, the water contains sufficient hydrogen sulphide in solution to give the appropriate color reactions with salts of silver, lead, cadmium, etc. If, again, the calcite be gently heated in a test-tube, hydrogen sulphide is liberated, and on heating somewhat more strongly the mineral generally decrepitates and gives off more hydrogen sulphide. On heating to 160° C. it shows a strong, deep yellow phosphorescence which persists for several minutes after removal from the source of heat.

From what has been stated it is evident that the hydrogen sulphide is the cause of the odor evolved when the calcite is scratched or rubbed, and although the quantity seems small when stated as percentage by weight it amounts to about 500 cubic inches of the gas per cubic foot of the mineral. Per cubic yard this would be about 13,500 cubic inches (a barrel and a half) of the gas, and the total quantity bottled up in the limestone of the region must be exceedingly large. It may exist in the calcite in a liquid condition, as in the case of the liquid carbon dioxide so frequently present in quartz, or in conjunction with water, or even with carbon dioxide. Mr. Douglas McIntosh, M.Sc., lecturer in chemistry, has kindly made some experiments for me which are interesting in this connection. He found that if solid carbon dioxide be dropped into liquid hydrogen sulphide and the tube sealed, as the temperature rises to that of the room the carbon dioxide dissolves and a homogeneous liquid is obtained, giving no evidence so far as appearance is concerned of the presence of two distinct compounds.

A small quantity of distilled water, again, was put into a tube and frozen, an equal volume of liquid hydrogen sulphide added and the tube sealed. When the ice melted, the two liquids could be seen to be separated by a distinct film—possibly of sulphur—which prevented their intermixing. In most cases when the tubes were heated they burst before the temperature reached 100° C. The same was also true if the tubes were inverted in position, that is with the water above the hydrogen sulphide; after standing for a short time the film gave way and the tube burst, possibly because of some sudden reaction between the two liquids. In one case, however, a tube which showed the distinct film separating the two liquids was forgotten and allowed to stand for some weeks. The film had then disappeared and, so far as one could tell by the eye, the two liquids had completely intermixed. On cooling the tube until the water crystallized out and then allowing it to gradually attain the temperature of the room, no separation of the two liquids took place. This would indicate that under the conditions of pressure in the tube, mutual solution of the water and hydrogen sulphide had taken place, and similar conditions may exist in the case of the fluid-cavities of the calcite.

Sir William Logan, judging from his description, regarded the fetid calcite as a local modification of one of the great bands of limestone belonging to the Grenville series. This modification might have been due to some form of solfataric action going on at the time of crystallization and introducing hydrogen sulphide, one of the usual accompaniments of such action. The crystals of pale green tourmaline (a boron mineral) which occasionally occur in the calcite might also point to solfataric action, though no such assumption is necessary to account for its presence. The hydrogen sulphide, again, might be taken as an indication of the existence of organic matter in the old sediments of the Laurentian series; for, as is well known, organic matter in presence of water reduces alkaline and earthy sulphates to sulphides, which reacting with water and carbon dioxide produce hydrogen sulphide. On the other hand, however, the hydroden sulphide might have been produced from sulphides formed in the earth's crust quite independently of any organic agencies.

Associated with the fetid calcite there is also a white, translucent to subtranslucent quartz, which, on striking with a hammer or scratching with a knife, likewise evolves hydrogen sulphide. When fragments of the quartz are heated in a test-tube, considerable quantities of the gas are given off and readily darken lead acetate paper. No attempt has been made to estimate the proportion of the hydrogen sulphide in this case, nor does there seem to be any simple way of accomplishing this. In lump form the mineral would dissolve too slowly in hydrofluoric acid, while if powdered most of the hydrogen sulphide would escape. On heating the fragments, too, only a portion of the gas can be liberated and that in part at least is liable to undergo dissociation at the temperature of the experiment. The fluid-cavities in the quartz are, however, larger than in the calcite and more readily admit of study. Most of them afford no visible evidence of the presence of more than one liquid, and the moving bubble which they contain does not disappear on heating to 150° C—the highest temperature tried. In a few cases the bubbles disappeared at from 32°–35° C., indicating, no doubt, that the cavity contained liquid carbon dioxide whose critical temperature is 32° C. In one case the critical point was 40° C, and in several others from 60°–65°, indicating, possibly, mixtures of carbon dioxide and hydrogen sulphide, the critical point of the latter being about 100° C. In cases where the bubbles did not disappear water is evidently present, accompanied no doubt by hydrogen sulphide and possibly by carbon dioxide as well. Some of the cavities, again, appear to contain two separate liquids with a bubble in one of them.

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## Art. XXXVII.—*Alternations of Large and Small Coronas observed in Case of Identical Condensations produced in Dust-free Air saturated with Moisture;*[*] by C. Barus.

1. *Apparatus.*—By dust-free air, I mean air which has been passed through a packed cotter filter. My filters are 16 inches long, conical, tapering from about 2 inches in diameter at the large end to about one-half inch at the other. They contain absorbent cotton rammed in from both ends and kept in place by wire. When filtered air is required, the stop-cock is only just opened so that influx of dust-free air may be extremely slow. This insures proper filtration and does not interfere with the saturation of the air in the fog-chamber. In this paper condensation was produced in a long glass cylinder, 16 inches from end to end and 5½ inches in diameter, placed horizontally and normal to the line of sight. It contained a rectangular framework of copper wire covered with wet cotton cloth, except on the two opposed broadsides through which the coronas were observed. The distance between the bottom (water) and the roof of the rectangular framework was about 9 centims. The provisions for keeping the air saturated are thus ample.

The vacuum chamber was a large boiler of galvanized iron, having a capacity $V$, of over 100,000$^{\text{cub cm}}$, while the capacity $v$, of the condensation chamber is about 6,700$^{\text{cub cm}}$, so that the volume ratio, $v/V$, is but ·063. The two chambers are connected by about a foot of rubber tubing over one inch in bore, usually containing a one inch plug gas cock. An instantaneous clapper valve of the same dimensions and opened with a hammer was often used for comparison. Later the glass fog-chamber was advantageously replaced by one of waxed wood (cf. this Journal, xlix, p. 175, 1905), with the opposed sides, through which the coronas were observed, made of plate glass. The internal dimensions in this case were $55 \times 10 \times 20^{\text{cub cm}}$, and the volume ratio, $v/V$, in connection with the vacuum chamber about ·13.

2. *Manipulation.*—The experiments were conducted as follows: Having selected a suitable pressure difference above that at which condensation in dust-free air just begins (usually termed the *fog-limit* in the present paper), the dust-free moist air in the closed condensation chamber at atmospheric pressure is suddenly exhausted and the corona measured. After all fog has subsided the exhaustion cock is closed and the filtered air very slowly admitted. The operations are then repeated allowing time (about 2–3 min.) for saturation. Under all circumstances the treatment for large and small coronas was identical.

In the given apparatus, condensation in dust-free moist air began at the pressure difference, $\delta p = 22{\cdot}5$ for an atmosphere of $76^{cm}$ corresponding to the volume expansion of about 1·43. The pressure difference usually applied in the experiments was $\delta p = 31·2$, and the volume expansion 1·72.

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[*] Read to the Am. Physical Soc., Feb. 25, 1905.

3. *Alternation of large and small coronas* (*periodicity*). *Data.*—The small coronas are usually sharp; but the large coronas appear blurred and filmy, accompanied with much rain. Remembering that all operations are conducted in a way strictly the same, the annexed figures 1 to 4 shows the coronas seen in the successive exhaustions. The angular diameter or aperture is $\sin \phi/2 = s/60$, or nearly $\phi = s/30$. The eye at the goniometer was about $40^{cm}$ from the axis of the condensation chamber (placed as close as possible to insure clearer vision) and the source of light $250^{cm}$ beyond it. Observations were made along the axis of the cylinder, placed horizontally.

In the case of 2 min. periods between the exhaustions (fig. 1) the periodicity is maintained without exception. For brevity let the smaller coronas be called inferior, the larger coronas superior. Frequently a very small inferior corona $l$ evokes a relatively large superior corona $h$, or larger inferior coronas are followed by smaller superior coronas; but this is not always the case. As a more general rule, if the aperture is intermediate between the inferior and superior coronas, the succeeding corona is of the same size and oscillation terminates. Similar remarks may be made relative to the diagram, fig. 2, for $3^m$ periods between the exhaustions, or for fig. 4, for the case of dust-free air energized by weak radium (10,000 ×) in sealed glass tube.

4. *Remarks on the results.*—It will conduce to clearness to take the increase of apertures, $s$, with the increase of pressure difference, $\delta p$, first in order. If the exhaustion is insufficient, the groups of smaller nuclei will escape precipitation and the coronas be relatively small. After all nuclei, large and small, are caught, higher sudden exhaustion can no longer increase the apertures. More water is instantaneously precipitated per cubic centimeter. Nevertheless this counter-effect, if it is such, will also vanish with increasing pressure differences, because of the accentuated rapidity of thermal radiation. The adiabatic method ceases to be effective. Finally the necessity of producing sudden cooling simultaneously with extreme dilatation is a complication; for in view of the relative slowness of diffusion, it will eventually be impossible to keep the instantaneously dilated water vapor saturated, without arresting the growth of the fog particles. Above $\delta p = 40^{cm}$ the effect of sudden exhaustion may be conceived to actually dry the air, seeing that the density of vapor is instantly reduced more than one half, and hence even slight differences of supersaturation at the outset may show themselves effectively at these high exhaustions. Experimentally (figs. 6 and 7), these surmises are not fully

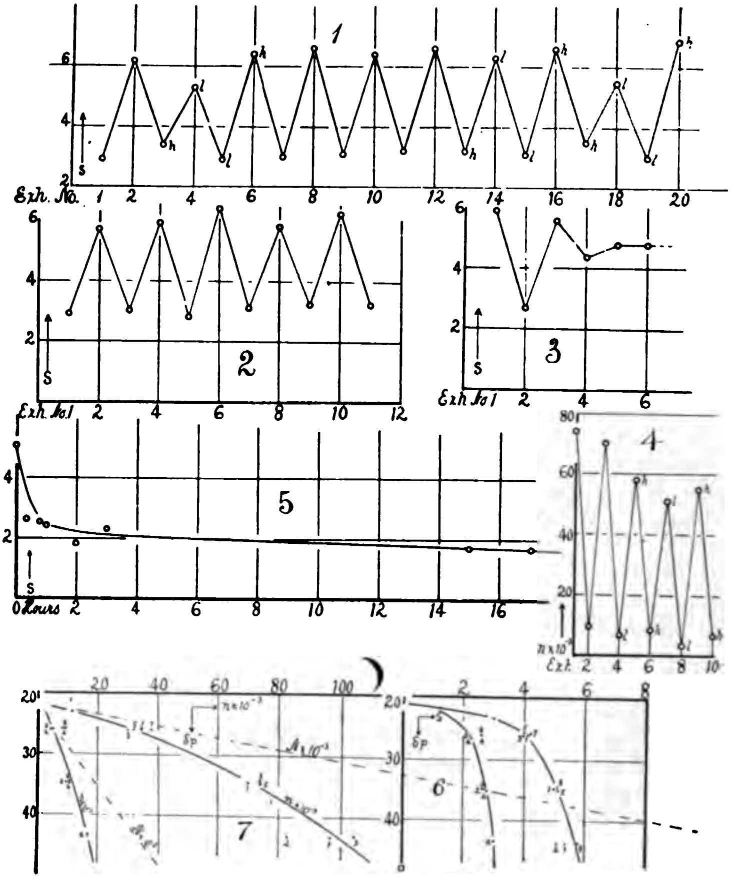
borne out: while the *s*-curves usually tend to reach an asymptote or a maximum, the N-curves (number of nuclei per $cm^3$ computed for normal pressure and temperature) do not usually do so, at least so far as observed in the case of non-energized air.

5. *Blurred coronas.*—The occurrence of an abundance of rain with all the coronas, as well as the blurred appearance of the coronas themselves, shows that gradation of particles is a characteristic feature with all these condensations. The following results for periodicity apparently indicate the presence of a group of markedly large particles in the amount of about 1/8 or more of the total number of nuclei.

6. *Time loss of nuclei.*—In the lapse of time exceeding even half an hour (cf. fig. 5) the aperture of all coronas usually diminishes in marked degree. Above the fog-limit, however, the coronas do not vanish as the result of repeated exhaustion; i. e., the air can not be freed from nuclei by being stored in a closed vessel. What is particularly remarkable is the rapidity with which nuclei precipitated by condensation are again replaced. Whether these come through the filter in quasi-gaseous form, or whether they are spontaneously produced in the imprisoned air is yet to be decided. In every case something has to be explained away. If the nuclei came through the filter, for instance, they would not come periodically. If inferior coronas were due to undersaturation, superior coronas should be obtained in the lapse of time; the reverse of which is observed.

7. *Effect of pressure difference.*—With increasing pressure differences, $\delta p$, the superior and the inferior apertures each lie on distinct curves, as in figures 6 and 7, both of which rise rapidly at first, are then rapidly retarded and tend to reach distinct maxima. The limiting ratio of apertures is liable to be nearly one-half. If, however, the pressure difference is carried far enough, both *s*-curves sometimes change character by decreasing and increasing respectively, eventually to reach a common value. If then pressure difference is in turn reduced from these final values, the oscillation of *s* is usually absent and a mean nucleation appears at all subsequent (decreasing) pressure differences.

8. *Continued.*—The increase of nucleation, *n*, or N, with the pressure difference, $\delta p$, is often difficult to interpret, since the inferior and superior values are so much more widely and irregularly distributed. The *n*-curves usually show two limiting rates of increase of *n* with $\delta p$, respectively very large and very small. This is particularly well brought out in the data of figure 7 where both loci are nearly straight even above $\delta p = 40^{cm}$. Inferior coronas are sometimes absent and those observed present an accentuated case of superior corona; and vice versa.



LEGENDS FOR FIGURES.

Curve 1.—Periodicity of dust-free air, showing the angular apertures of coronas (ordinates *s*) in successive identical exhaustions (numbered by abscissas), made at two-minute intervals apart. Note that high (*h*) inferior coronas are usually followed by low (*l*) superior coronas and vice versa; while high superior coronas are followed by high inferior coronas. $\delta p = 31{\cdot}2^{cm}$.

Curve 2.—The same for three-minute periods between the exhaustions.

Curve 3.—The same for five-minute periods. Periodicity gradually vanishes.

Curve 4.—Periodicity of dust-free air energized by radium (10,000 ×) in glass, within the fog chamber. The successive exhaustions gradually reduce the nucleation. Sequences of *h* and *l* are apparent. The ordinates are number of nuclei per $cm^3$. $\delta p = 25^{cm}$.

Curve 5.—Dust-free air not energized, showing the reduction of nucleation (decreasing apertures, *s*) in the lapse of time.

Curve 6.—Periodicity of apertures (*s*) at different pressure differences $\delta p$. The number of the exhaustions is attached to the observation. The loci of inferior and superior coronas are well marked.

Curve 7.—The same computed for number of nuclei (*N*) in one cub. cm. of air at normal pressure.

9. *Fog-limits.*—An interesting feature of these results are the fog-limits or pressure differences at which condensation in dust-free air just commences. In spite of the different sizes of apparatus and valves used, the fog-limits are about the same, viz.:

| | | |
|---|---|---|
| $\delta p = 22$–$23$ | Apparatus, wood, $v/V = \cdot 13$ | Valve, plug. |
| 21·5– | " glass, $v/V = \cdot 06$ | " clapper. |
| 22–23 | " " | " plug. |
| 21–23 | " " | " clapper. |
| 22–23 | " " | " plug. |

These results are surprising, inasmuch as the effect of the volume ratio of fog and vacuum chambers and the valve effect would naturally be looked to as productive of larger differences. With other apparatus (this Journal, vol. xix, p. 175) the data were

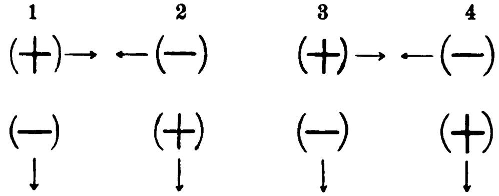
| | | |
|---|---|---|
| $\delta p = 22$ | Apparatus, wood, $v/V = \cdot 7$ | Valve, plug. |
| 20 | " " $\cdot 7$ | " clapper. |

Thus the supreme importance of mere rate of exhaustion may well be called in question until more definite results appear; for with so large a difference of volume ratio $v/V$, of valve obstruction, etc., the essential features should appear more clearly. One may note that if colloidal molecules (extremely fine nuclei) pass through the filter, these would capture most of the moisture on condensation. It is possible therefore that if the filter is dispensed with and a closed vessel used, larger coronas will appear at smaller pressure differences for this reason.

10. *Alternations of large and small coronas.*—Effectively, the case of oscillation is one in which the large sparsely distributed fog particles emit more nuclei and the very abundant small fog particles fewer nuclei; i. e., the phenomena may be looked upon as though the nuclei were generated during the growth of the fog particles. This plausible explanation, however, is not easily maintained; for the emission would have to be as the growth of surface, in other words as the volume, and the number of particles varies inversely as their volume. A counter supposition may be hazarded to the effect that the fog particles of large coronas absorb more nuclei because of their abundance than the fog particles of small coronas. But the period of suspension of particles is too short to be of moment.

If negative ions are more active as condensation nuclei than positive ions, the results observed may be tentatively grouped in according with the following scheme (see diagram, p. 354).

Let the ions be originally neutral as a whole, and suppose, as in case 1, that the negative ions are first precipitated. In the interval between this and the next exhaustion fresh ions are generated or taken in through the filter, as shown in case 2. If these negative ions partially neutralize the positive ions left over in case 1, the second precipitation takes place on the positive ions. Thereafter, case 3, the first is repeated, etc. But if the coronas are taken as a measure of the number of particles, the number of effective nuclei must be about eight times larger in the first case than in the second, whereas the ions should be present in equal numbers. Hence there is serious objection to this hypothesis at the outset, quite apart from the numbers obtained, which are enormously too large.



11. *Undersaturation.*—Some mechanism of this kind is nevertheless probable, and it will work equally well if the undersaturation produced by the precipitation of fog particles is not rapidly made up by diffusion and convection. Of all hypotheses that of undersaturation has the broadest bearing and accounts qualitatively for most of the phenomena, as will presently be pointed out in detail. True, the large coronas must be supposed to carry down more moisture than the small coronas, but the difference need not be great. The hypothesis encounters a serious obstacle inasmuch as the coronas obtained from saturated air which has been imprisoned for long intervals of time (§ 8), are usually an extremely small type of inferior corona, whereas they should be large superior coronas. Long intervals of waiting between exhaustions brings out not a superior corona but at best one of intermediate size. Another precarious feature is suggested by computating the rate at which saturation should be established in the most unfavorable case of the middle air layer, between the wet top and bottom of the fog chamber, for diffusion alone.

In fact if diffusion takes place from the wet top and bottom of the rectangular trough of height $a$, into a partially saturated atmosphere of initial vapor pressure $p_0$, then at any time $t$, at the middle plate $x = a/2$

$$p = 1 + \frac{4(p_0 - 1)}{\pi}\left(\sin\frac{\pi}{2}\,\epsilon^{-(\pi/a)^2kt} + \frac{1}{3}\sin\frac{3\pi}{2}\,\epsilon^{-(3\pi/a)^2kt} + \text{etc.}\right)$$

where $dp/dt = k\ (d^2p/dx^2)$. Hence if $a = 11^{\text{cm}}$ as in the largest trough (wood), and if $k = \cdot 23$, the following values obtain.

| | | | |
|---|---|---|---|
| $t =$ 30 | $p_0 = 0,\ p =$ ·28 | $p_0 = 1/3,\ p =$ ·52 | $p_0 = 2/3,\ p =$ ·76 |
| 60 | ·59 | ·72 | ·86 |
| 120 | ·87 | ·91 | ·96 |
| 180 | ·96 | ·97 | ·99 |

In the above tables *a* was usually less than $10^{cm}$ (glass fog chamber), making the condition correspondingly favorable.

Hence by diffusion alone there should be saturation after two to three minutes even at the most distant (middle, $x=a/2$) plane, to within a few per cent; for the central layer is probably always more than half saturated at the outset. In addition to diffusion, however, there is marked convection due to the lightness of water vapor. At the same time there is no evidence that the more numerous but small drops of the superior coronas carry down a sufficient excess of water; nor are the coronas, though blurred otherwise distorted, as they would be for a definite diffusion gradient.

12. *Continued.*—Assuming however that undersaturation does occur and is oscillatory as the result of successive larger and smaller precipitations, the cases may be interpreted in succession as follows;

*a.* The superior coronas carry down more moisture and should apparently be followed by even larger coronas; and vice versa: but after the fog particles producing the superior coronas are precipitated, the supersaturation possible for the given pressure difference applied no longer catches the small nuclei. Hence the inferior coronas appears in succession. Hence also, apart from what may be time errors in opening the stopcock, very large pressure differences tend to wipe out the oscillation as all the nuclei are captured.

*b.* The ratio of 1:2 for coronal apertures and of 1:8 for the numbers of fog particles seems out of keeping with the slight differences of supersaturation instanced in 13; but this is again a question of catching the smaller nuclei as a group.

*c.* The phenomenon is much too definite an oscillation of aperture between *s* and 2*s* (nearly) to be referable to an irregular cause like deficient supersaturation; but the two types of nuclei admit of a wide range of saturation, as long as there is a correspondingly wide difference in the sizes of nuclei.

*d.* A series of minor observations are favorable to the hypothesis of residual undersaturation; as for instance, the eventual coalescence of the aperture curves of the superior and the inferior coronas; the dew effect; the fog effect and shaking; the fact that very small inferior coronas are followed (caet. par.) by large superior coronas while the latter are followed by large inferior coronas, etc.

*e.* Finally, while superior coronas are followed by inferior coronas and vice versa, mean coronas follow each other.*

13. The values of the nucleation (number of nuclei per cub. cm.) of the inferior and the superior coronas naturally

---

* I have since proved that periodicity is due to the formation of water nuclei by evaporation. On these the inferior coronas condense. Points *a* to *e* then follow. The ions become solutes.

present a more striking contrast, since the third power of aperture is involved. Otherwise but few new results are to be inferred from them. If the long series of figure 1 be taken, which contains the data of twenty successive alternations, the average inferior nucleations are 11,800, and the average superior nucleations 94,000, supposing, of course, that the precipitated water is the same in both cases and that it is all condensed on the available nuclei. In other words, if the two cases are otherwise identical, the superior coronas correspond to a number of nuclei eight times greater (frequently larger than this in the other observations) than the inferior coronas. As this explanation is the more probable, it follows that the nuclei (as stated in §10) cannot be regarded as positive and negative ions. They are rather the groups of large and small nuclei seen throughout the condensations in connection with the rain and the blurred coronas. Apart from this the numbers obtained throughout are quite out of keeping with any similarly observed ionization. If, however, free electrons appear only at the destruction or at the origin of nuclei, the association of few ions with many nuclei at any time subsequent to their origin, is well accounted for, as already suggested in the earlier paper. It is only while the nuclei are being produced that the ionization and the nucleation must be of the same order; for the latter persists while the former vanishes at once. Finally the following results are implied at least for the physical structure of air saturated with water vapor:

Air (dust-free) is inseparably intermixed with large and small nuclei, whose number (to be reckoned in millions per cubic centim.) rapidly increases as the order of molecular size is approached. There seems to be no objection to looking upon these nuclei as a kind of colloidal (air) molecule, particularly as such molecules are frequently producible by the means (Bredig) which produce nuclei. If a large number of free atoms is suddenly introduced into any region (and this is probably what the radiation of the above kind virtually does), the result is not merely a production of typical molecules but of a large concomitant of graded nuclei.

Practically any given nuclear status of air is a counterpart of the intensity of the ionization of the medium in which the nucleation originated, to the effect that the superior limit of size of the nuclei and their number increase with the ionization. But there is no case of ionization free from nucleation, be the exciting cause a mere radiation as above, or ignition, combustion (including the low temperature cases like phosphorus), or high potential discharge, or violent comminution as in the case of water nuclei,—the two manifestations being *often* distinguishable by enormously different rates of decay.

*Brown University, Providence, R. I.*

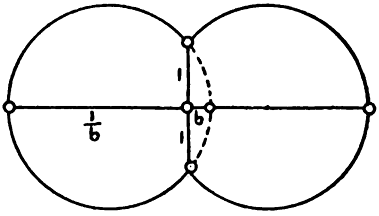
## ART. XXXVIII.—*New Circular Projection of the Whole Earth's Surface*; by ALPHONS J. VAN DER GRINTEN, Chicago.

THE representation of the surface of a sphere upon a plane is a problem which has occupied the attention of cartographers for centuries. The problem has been solved in many ways, but always at some sacrifice of form or relation of parts, depending upon the requirements of conformity or equivalence.

Conformal projections necessarily exaggerate the areas toward the margin (Eisenlohr, August, et al.), while the equivalent ones (Werner, Mollweide, Sanson) reduce the angles formed by the intersection of parallels and meridians considerably. Each of these devices introduces such errors of representation that a comparison of areas and places in the different parts of the globe becomes rather difficult. A third principle, introduced in an attempt to distribute these errors over the map, also fails to obtain the most favorable result, an increase of distortion in tropical latitudes hardly being offset by an increase in accuracy in the less important polar regions.

These conditions, therefore, make desirable a new method of projection, by which all the deformations shall increase regularly from a zero value at the equator to the least possible maxima at the poles. The network may be formed exclusively by straight lines and circular arcs, as the polar flattening can be neglected as unimportant in a map of so small a scale as is required to represent the whole earth's surface.

1



The device of using circular arcs for parallels and meridians results in the production of an apple-shaped marginal meridian, having the central meridian and the equator as straight lines. If $b$ represents the ratio of the lengths of these main lines of the projection, a mathematical investigation shows that the most favorable expression of the total deformation, dependent upon the elements $h$, $k$ and $\Theta$, as will be shown later, is obtained when the two circles, the marginal meridians of the two hemispheres, cover each other, so fusing into one true circle: $b = 1$. The mathematical deduction as given here, for this case, is based upon Tissot's theories of deformation, as given in his famous "Mémoire sur la représentation des surfaces et les projections des cartes géographiques"

(1881), augmented by E. Hammer in "Die Netzentwürfe geogr. Karten, von A. Tissot, 1887."

J. H. Lambert (1772) was the first to recognize the circular form as the most natural one for the representation of the whole globular surface, but failed to notice the fact that his conformal projection would admit of a simple geometrical construction. Even the most modern treatises on projections reprint his table containing the numerical values of the distances $d$ and $s$ of the parallels and their centers from the equator. Recently Zöppritz, Reclus and others have urgently recommended the circular form of representation, not only for the whole earth, but for parts of it as of the continents. Although Lambert's projection must be considered as a theoretical "Unicum" its insufficiency for practical purposes becomes evident, in the stereographic arrangement of the meridians, and the subsequent primary subdivision $\left(c = \tan\frac{\phi}{2}\right)$ of the central meridian, reducing too much the central parts of the map as compared with those near the margin.

In order to remedy this defect, I am proposing a projection in which the meridians intersect the equator at equal distances, and then the distances and curvatures of the parallels are altered in such a way that no alteration whatever occurs along the equator. Then we readily obtain our distance $d$, by substituting $c = \frac{\phi}{90}$ for $c = \tan\frac{\phi}{2}$ in Lambert's formula

$$d = \frac{\sqrt{1+\tan\frac{\phi}{2}} - \sqrt{1-\tan\frac{\phi}{2}}}{\sqrt{1+\tan\frac{\phi}{2}} + \sqrt{1-\tan\frac{\phi}{2}}}\quad\text{thus:}$$

$$d = \frac{\sqrt{1+c} - \sqrt{1-c}}{\sqrt{1+c} + \sqrt{1-c}} = \frac{1-\sqrt{1-c^2}}{c} = \frac{\sqrt{90+\phi} - \sqrt{90-\phi}}{\sqrt{90+\phi} + \sqrt{90-\phi}},$$

which can just as easily be constructed geometrically (see figure 2) as that of Lambert.

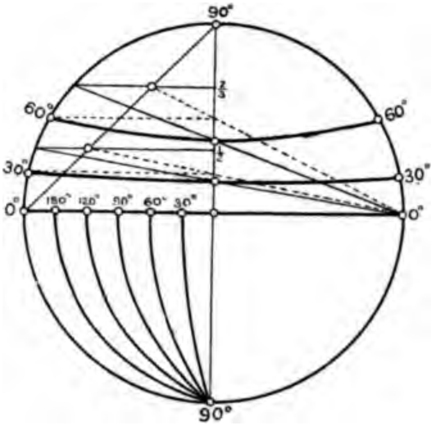
It now remains to determine the distance from the equator ($y$) of the intersecting point of any parallel and any marginal meridian, in such a manner that the distortion of angle ($\Theta = 90 - \eta$) formed by them be a minimum; inasmuch as the requirement of a minimum $2\omega$ would necessitate a maximal $\Theta$ between the equator and the poles, as will be explained later in this paper.

$y$ can be determined in different ways. If a rectangular network is proposed ($\Theta = 0$), we find $y = c = \frac{\phi}{90}$; if the parallels are to run as straight lines parallel with the equator, we have $y = d$, in which case, although equivalence and conformity are preserved along the equator, $\Theta$ increases to 90° at the poles ($\eta = 0$); and finally if it is required that the deformation ($\kappa$) of any parallel at the marginal meridian shall be equal to its deformation at the central meridian, in which case all the parallels are practically intersected by the meridians at equal distances, we get

$$y = d\,\frac{3-d^2}{2}\,.$$

By the first arrangement (rectangular trajectories) the parallels at the margin would approach too near to the poles ($h$ representing the deformation of meridional parts, $\phi$ the latitude, and $\lambda$ the longitude):

2



GEOMETRICAL CONSTRUCTION
*Patented in U.S. Canada, Gr. Britain & France.*

$$h_{\lambda=180}^{\phi=0} = 2;\; h_{\lambda=180}^{\phi=90} = h_{\lambda=0}^{\phi=90};$$

in the second case they would appear to be too far distant from the poles:

$$h_{\lambda=180}^{\phi=90} = \infty\,.\,h_{\lambda=0}^{\phi=90};$$

finally in the third case we are confronted with an unhappy congestion of the temperate zones:

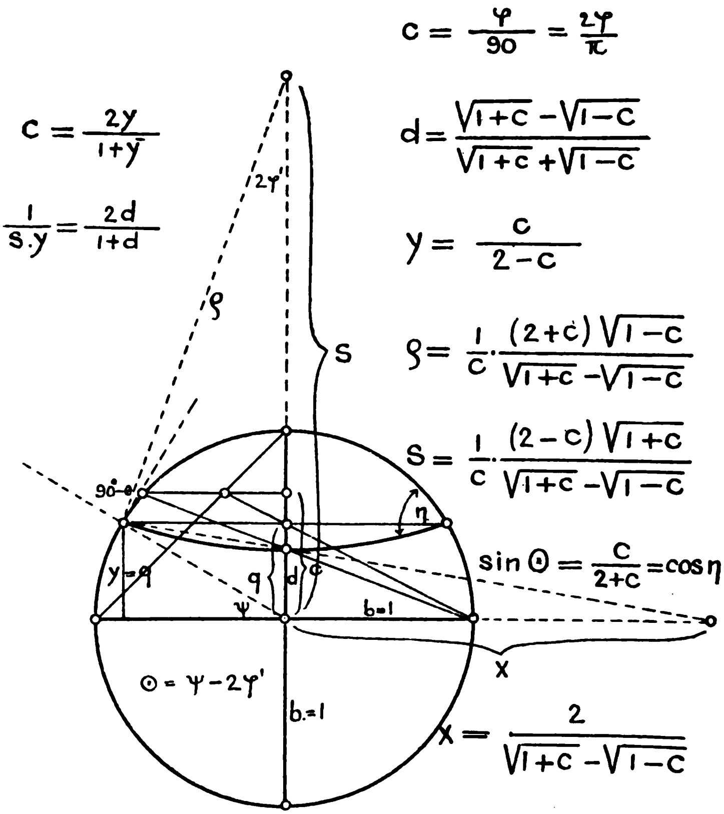
$$h_{\lambda=180}^{\phi=0} = \tfrac{3}{2};\; h_{\lambda=180}^{\phi=90} = \sqrt{3}\cdot h_{\lambda=0}^{\phi=90}\,.$$

Therefore it seems desirable to find a middle ground by having all alterations continuously increased from zero at the equator to their least maxima at the poles:

$$h_{\lambda=180}^{\phi=0} = 1;\; h_{\lambda=180}^{\phi=90} = \sqrt{2}\cdot h_{\lambda=0}^{\phi=90}\,.$$

This arrangement has the effect of making the continental regions fall within the zone of least "total error," though this term must be used with reserve as no exact definition of it can be given; linear, angular, and areal values being of a heterogeneous character. Here it is the simplicity of the formula or construction which proves its superiority in the solution of an intricate problem.

3


$c = \frac{\varphi}{90} = \frac{2\varphi}{\pi}$
$c = \frac{2y}{1+y}$
$\frac{1}{s.y} = \frac{2d}{1+d}$
$d = \frac{\sqrt{1+c}-\sqrt{1-c}}{\sqrt{1+c}+\sqrt{1-c}}$
$y = \frac{c}{2-c}$
$\varrho = \frac{1}{c} \cdot \frac{(2+c)\sqrt{1-c}}{\sqrt{1+c}-\sqrt{1-c}}$
$S = \frac{1}{c} \cdot \frac{(2-c)\sqrt{1+c}}{\sqrt{1+c}-\sqrt{1-c}}$
$\sin \odot = \frac{c}{2+c} = \cos \eta$
$X = \frac{2}{\sqrt{1+c}-\sqrt{1-c}}$
$2\varphi'$
$\varrho$
S
$90°-\odot$
$\eta$
$y=q$
q
d
c
$\psi$
b=1
X
$\odot = \psi - 2\varphi'$
b.=1

The formula for our $y$ can easily be developed by the following reasoning (fig. 3). The proportion

$$\frac{x}{x+\sqrt{1-y^2}} = \frac{d}{y} \text{ gives } y = d\,\frac{x^2+\sqrt{x^2(1-d^2)+d^4}}{x^2+d^2}.$$

Now in order to preserve conformity and equivalence along the equator (the meridians here being equidistant) we can substitute for $x$ the arbitrary value $\frac{a}{d}$, which is to be so determined, that $y$ comes nearest to $c = \frac{\phi}{90}$ for rectangular projection, making $\Theta$, continuously increasing, a minimum. The above expression then is

$$y = d\,\frac{a^2 + d\sqrt{a^2(1-d^2)+d^4}}{a^2+d^4}\,;\ \text{and as}\ \sqrt{a^2(1-d^2)+d^4}$$

cannot exceed the unit ($d = 1$; $y = 1$), $y$ will become a maximum, under the limitation $x^{\phi = 0} = \infty$, and, therefore, $\Theta$ a minimum, just when $\sqrt{a^2(1-d^2)+d^4}$ is made a unit, giving $a = \sqrt{1+d^2}$, or $x = \frac{\sqrt{1+d^2}}{d}$, and finally $y = \frac{d}{1-d+d^2} = \frac{c}{2-c}$ and $\sin\theta = \sin(\psi - 2\phi') = \frac{d}{1+d+d^2} = \frac{c}{2+c}$. Any other value for $a$, less than $\sqrt{1+d^2}$, would produce a maximum of $\Theta$ between the equator and the poles. This maximum would reach its climax for $a = 1$, $x = \frac{1}{d}$ ($\Theta = 0$ at the equator and at the poles), the determination and location of which would require the solution of a very lengthy equation. The requirement of a minimal $2\omega$ involves a much more intricate equation still for the determination and location of the maximal $\Theta$ that is formed between the equator and the poles.

The harmonic relation between $y$, $c$ and the radius of the marginal meridian (= unity) is then defined by $c = \frac{2y}{1+y}$. Other harmonic relations occur at latitudes 72° and 54° as $y = \frac{2d}{1+d^2}$ and $y = \frac{2cd}{c+d}$ respectively.

I now offer the formulas of deformation in the most condensed form, which will furnish the necessary data for a table showing the most characteristic features of the circular projection in a numerical way; and which will enable the student of cartography to extend the table to apply to any interval of latitude whatsoever.

### *Deformation.*

The deformation of an infinitely small part of the central meridian at a point $\left(\begin{matrix}\phi\\ \lambda\end{matrix}\right)$ is expressed by the ratio $h_{\lambda = 0} = \frac{\delta d}{r\delta\phi}$, $r$ representing the radius of any globe. It being necessary to have $h_{\lambda = 0} = k_{\lambda = 0} = 1$ at the center of the map, we get

$$r = \frac{\delta d}{\delta \phi_0},\ h_{\lambda = 0} = \frac{\dfrac{\delta d}{\delta \phi}}{\dfrac{\delta d}{\delta \phi_0}}$$

consequently (I) $h_{\lambda=0} = \frac{2}{c} \cdot \frac{\sqrt{1+c} - \sqrt{1-c}}{(1+c)\sqrt{1-c} + (1-c)\sqrt{1+c}}$.

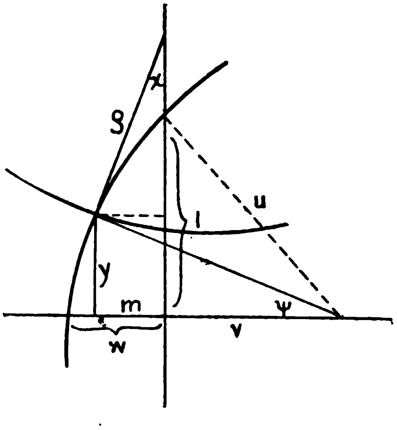
The deformation of an infinitely small meridional part at the margin is defined by $h_{\lambda = 180} = \frac{\delta \psi}{r \delta \phi}$. Now having $\sin \psi = y$, we finally get

$$\text{(A)}\ h_{\lambda = 180} = \frac{y}{d} \cdot \frac{\sqrt{1-y^2}}{1-dy} \cdot h_{\lambda = 0},$$

and in our case

$$\text{(II)}\ h_{\lambda = 180} = \frac{4}{(2-c)[(1+c)\sqrt{1-c}+(1-c)\sqrt{1+c}]} = x.y.h_{\lambda=0}.$$

4



The deformation of a part of a parallel between two infinitely approximate meridians is explained by

$$k = \frac{\rho \delta x}{r \cos \phi \delta \phi} = \frac{\rho}{r \cos \phi} \cdot \frac{\delta(2\phi^1)}{\delta \phi},$$

from which is obtained the general formula

$$k = \frac{1}{r} \left( \frac{\delta u}{\delta \lambda} - \frac{\delta v}{\delta \lambda} \cos \psi \right) \cdot \frac{\dfrac{\delta w}{\delta \lambda}}{\cos \phi \cos \theta}$$

wherein $u$ denotes the radius of any meridian, $v$ the distance of its center from the central meridian and $w$ the linear longitude. There we have $v = \frac{1-w^2}{2w}$; $u = \frac{1+w^2}{2w}$ and $\frac{\delta v}{\delta \lambda} = -\frac{1+w^2}{2w^2} \cdot \frac{\delta w}{\delta \lambda}$; $\frac{\delta u}{\delta \lambda} = -\frac{1-w^2}{2w^2} \cdot \frac{\delta w}{\delta \lambda}$ and substituting $k = \left(\frac{m}{w}\right) \frac{1}{\cos \phi}$, where $\left(\frac{m}{w}\right)$ becomes indefinite $= \frac{0}{0}$ at the central meridian, and find: $\left(\frac{m}{w}\right) = 1 - d^2$; $k_{\lambda=0} = \frac{1-d^2}{\cos \phi}$ or finally,

$$\text{(III)} \quad k_{\lambda=0} = \frac{2}{c} \cdot \frac{(1+c)\sqrt{1-c} - (1-c)\sqrt{1+c}}{\sqrt{1+c} + \sqrt{1-c}} \sec \phi.$$

For the deformation $k$ at the marginal meridian we get by the above general formula: $k_{\lambda=180} = \frac{\cos \psi}{\cos \phi \cos \theta}$, from which we derive: by (B) $\sin \theta = \frac{2d - y(1+d^2)}{1 - d(2y-d)} = \frac{c-y}{1-cy}$ the general expression: (C) $k_{\lambda=180} = \frac{1-d(2y-d)}{(1-d^2)^2} \cdot k_{\lambda=0}$ and for our $y = \frac{c}{2-c}$:

$$\text{(IV)} \quad k_{\lambda=180} = \frac{(2+c)\sqrt{1-c}}{(2-c)\sqrt{1+c}} \sec \phi = \frac{\rho}{s} \sec \phi.$$

The deformation of area at the central and marginal meridians is defined by

$S_{\lambda=0} = h_{\lambda=0} \cdot k_{\lambda=0}$ and $S_{\lambda=180} = h_{\lambda=180} \cdot k_{\lambda=180} \cdot \cos \theta$, respectively.

The maximal and minimal linear alterations are then represented by the conjugate diameters $a$ and $b$ of an infinitely small ellipse—called the indicatrix—which is produced by an orthogonal projection of an infinitely small circle—circumscribing a point $\left(\frac{\phi}{\lambda}\right)$—from any curved surface upon a plane. These diameters are defined by the relations:

$$a^2 + b^2 = h^2 + k^2$$
$$a \,.\, b = s = h \,.\, k \,.\, \cos \theta$$

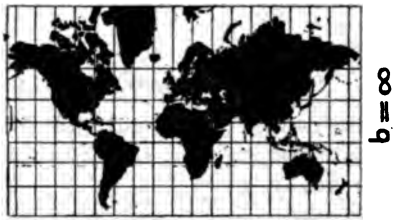
and the maximal distortion of angle ($2\omega$) by

$$\sin \omega = \frac{a-b}{a+b} = \sqrt{\frac{h^2 + k^2 - 2hk \cos \theta}{h^2 + k^2 + 2hk \cos \theta}}.$$

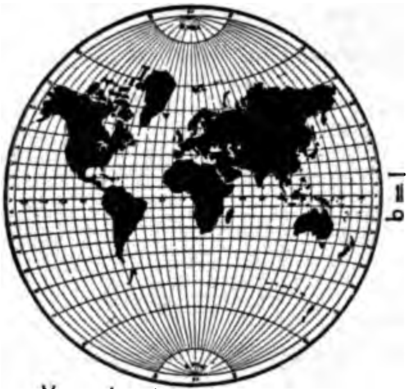
The $y = d\,\frac{3-d^2}{2}$ projection coincides with ours for $d = \frac{\sqrt{5}-1}{2}$; $\theta = 18°$; $\phi = 80°, 46$ (sectio divina).

A minimum $2\omega$ value coincides with our minimum $\theta$ in a latitude, where we have to surmount the difficulty of fairly representing the most northern parts of the continents of America and Asia ($\phi = 68°$ rot., see table).

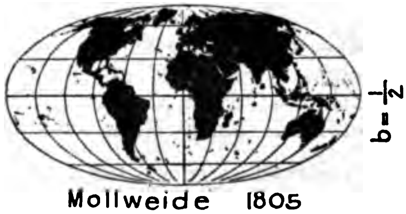
5



Mercator 1569



Van der Grinten 1898



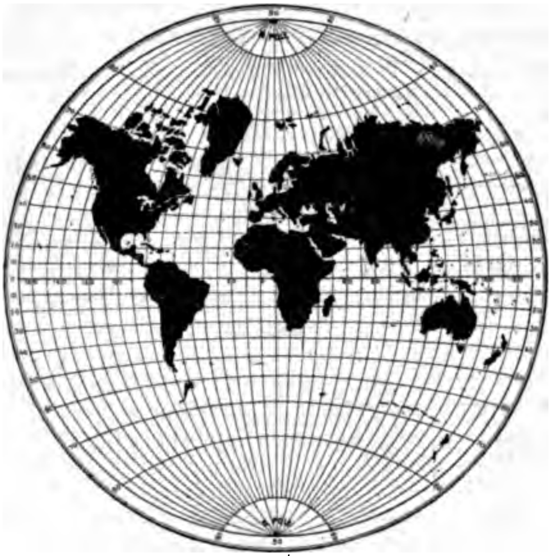
Mollweide 1805

Our circular representation can also be considered as a transformation of the two hemispheres into the most natural planisphere, the circumference of which is equal to the circumferences of the two hemispheres combined, so that we always have the superficial area of a globe of half the diameter before our view.

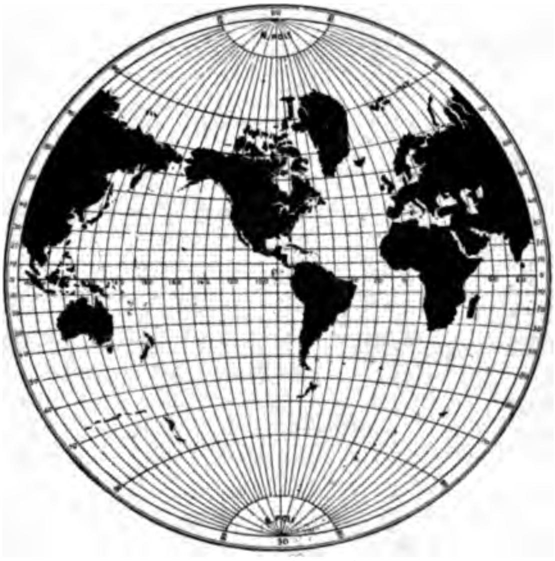
Fig. 5 will serve to compare same with those of Mercator and Mollweide, of which the latter has recently been supplanted by the Aitoff-Hammer "equivalent" projection showing a little improvement in regard to the distortion of angle, leaving it, however, useless for the representation of polar exploration like that of Mercator's "conformal" with the distortion in the opposite direction. Furthermore, Mercator's design was not intended for geographical, but merely for maritime purposes, the loxodromic line appearing as a straight line:

"Nova et aucta orbis terrae descriptio ad usum navigantium emendate accomodata."

6



CONTINENTAL VIEW



AMERICAN VIEW

## II.

## TABLE OF APPROXIMATE VALUES OF DEFORMATIONS.

| $y$ | $h$ | $k$ | $\Theta$ | $2\omega$ | $S_{\lambda=180}$ | $\frac{S\lambda=180}{S\lambda=0}$ |
|---|---|---|---|---|---|---|
| Equator | | $\phi=0°$<br>$\lambda=0°$ | | | | |
| | 1,000 | 1,000 | 0° 0′ | 0° 0′ | 1,000 | |
| | | $\lambda=180°$ | | | | |
| $y=$ $d=0{,}000$ | 1,000 | 1,000 | 0° 0′ | 0° 0′ | 1,000 | 1,000 |
| $y=$ $\frac{c}{2\text{-}c}=0{,}000$ | 1,000 | 1,000 | 0° 0′ | 0° 0′ | 1,000 | 1,000 |
| $y=$ $c=0{,}000$ | 2,000 | 1,000 | 0° 0′ | 38° 56′ | 2,000 | 2,000 |
| Arctic and Antarctic Circles | | $\phi=66°\ 33'$<br>$\lambda=0°$ | | | | |
| | 1,768 | 2,025 | 0° 0′ | 7° 22′ | 3,580 | |
| | | $\lambda=180°$ | | | | |
| $y=$ $d=0{,}441$ | 1,969 | 2,513 | 26° 6′ | 30° 22′ | 4,443 | 1,241 |
| $y=$ $\frac{c}{2\text{-}c}=0{,}586$ | 2,568 | 2,116 | 15° 40′ | 19° 20′ | 5,233 | 1,462 |
| $y=$ $c=0{,}739$ | 2,967 | 1,693 | 0° 0′ | 31° 42′ | 5,023 | 1,403 |
| Minimum $2\omega$ | | $\phi=68°$<br>$\lambda=0°$ | | | | |
| | 1,853 | 2,109 | 0° 0′ | 7° 40′ | 3,908 | |
| | | $\lambda=180°$ | | | | |
| $y=$ $d=0{,}458$ | 2,084 | 2,670 | 27° 15′ | 31° 40′ | 4,947 | 1,266 |
| $y=$ $\frac{c}{2\text{-}c}=0{,}607$ | 2,704 | 2,208 | 15° 45′ | 19° 48′ | 5.743 | 1,469 |
| $y=$ $c=0{,}756$ | 3,058 | 1,745 | 0° 0′ | 31° 40′ | 5,336 | 1,365 |
| Harmonical Relations | | $\phi=72°$<br>$\lambda=0°$ | | | | |
| | 2,083 | 2,427 | 0° 0′ | 8° 44′ | 5,056 | |
| | | $\lambda=180°$ | | | | |
| $y=$ $d=\frac{1}{2}$ | 2,406 | 3,236 | 30° 0′ | 35° 32′ | 7,786 | 1,540 |
| $y=$ $\frac{c}{2\text{-}c}=\frac{2}{3}$ | 3.208 | 2,517 | 16° 39′ | 20° 40′ | 7,414 | 1,466 |
| $y=$ $c=\frac{4}{5}$ | 3,333 | 1,942 | 0° 0′ | 30° 36′ | 6,473 | 1.282 |
| Poles | | $\phi=90°$<br>$\lambda=0°$ | | | | |
| | ∞ | ∞ | 0° 0′ | 13° 35′ | ∞ | |
| | | $\lambda=180°$ | | | | |
| $y=$ $d=1{,}000$ | ∞ | ∞ | 90° 0′ | 180° 0′ | ∞ | ∞ |
| $y=$ $\frac{c}{2\text{-}c}=1{,}000$ | ∞ | ∞ | 19° 28′ | 30° 0′ | ∞ | 1,000 |
| $y=$ $c=1{,}000$ | ∞ | ∞ | 0° 0′ | 25° 38′ | ∞ | 0.500 |

## Art. XXXIX.—*On the Progress of the Albatross Expedition to the Eastern Pacific;* by Alexander Agassiz.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Acapulco, Mexico, February 24, 1905.]

We left the Galapagos (Wreck Bay) for Manga Reva on the 10th of January. On the northern part of this line we did but little work beyond sounding as we were likely to duplicate our former work to the eastward. The fourth day out, in latitude 5° south, we began a series of trawl hauls, surface hauls, and intermediate towings to 300 fathoms. In the northern part of the line to Manga Reva the hauls were remarkably rich as long as we remained within the influence of the western extension of the Humboldt Current, and as long as there dropped from the surface masses of the radiolarians, diatoms and Globigerinæ living in the upper waters. Some of the hauls were remarkable for the number of deep-sea holothurians and siliceous sponges. Among the former I may mention a huge Psychropotes, $55^{cm}$ long.

As we passed south and gradually drew out of the influence of the western current, we entered the same barren region we passed through to the eastward when going to and from Easter Island. By the time we reached latitude 15° S., the hauls became quite poor; this barren bottom district extended to within a short distance of Manga Reva; corresponding to it we found a most meager pelagic fauna, both at the surface and down to 300 fathoms—so poor that it could afford but little food to the few species, if any, living on the bottom in that region.

We arrived at Manga Reva on the 27th of January and found our collier awaiting our arrival.

While at anchor in Port Rikitea, we examined Manga Reva, the principal island of the Gambier group, from its central ridge on the pass leading from Rikitea to Kirimiro on the west side of Manga Reva, as well as from the pass leading to Taku. On both these passes we obtained excellent views of the barrier reef to the west, north and east of the Gambier Islands, and we could trace in the panorama before us the western reef extending in a northeasterly direction parallel to the general trend of Manga Reva Island for a distance of about 5½ miles.

From the northern horn to nearly opposite Kirimiro Bay the barrier reef has only three small islets; it is narrow, of uniform width, about ⅛ of a mile, plainly defined, submerged in places, and passing north bounds a large northern bight dotted with numerous interior coral patches from a quarter of a mile to a mile in diameter or length, with from 7 to 11 fathoms. The southern part of the western barrier lagoon off Manga Reva is irregularly dotted with many small patches of reef, with an occasional deep hole of from 15 to 20 fathoms near Manga Reva Island. From the islet to the west of Kirimiro there are but few coral patches, indicating a reef which dips gradually in a distance of a mile to a deep channel of from 4 to 6 fathoms, which separates the northern and western reef from the great reef flat lying to the southwest of Tara Vai. This flat has a width of nearly 2 miles, is about 4½ miles long, and is marked at its southwest extremity by a series of low islets arranged in a somewhat circular line, formed by three deep bays and spurs from the outer line of islets, as so frequently occurs on a wide reef flat in atolls of the Pacific.

This part of the reef is called Tokorua. It shelves very gradually from 3½ to 4 fathoms on the west face to 7, and connects with the plateau upon which stands Tara Vai and Agakanitai. From Tokorua the reef extends in an indefinite narrow ridge 8 miles long, with from 3 to 8 fathoms, in a southeasterly direction. The western edge is steep to, and the eastern face passes gradually into the lagoon, which at that point has a general depth of 8 to 20 fathoms. The deepest part of this region is at the foot of Mt. Mokoto between it and Tara Vai, though Tara Vai is united with Manga Reva Island by a plateau varying in depth from 3½ to 4½ fathoms.

At the southeastern point of the reef it passes into a wide plateau with from 9 to 10 or 15 fathoms. This plateau is about 9 miles wide southwest of Tekava. That part of the atoll has not been well surveyed, so that the position of the reef flat has not been ascertained further west on that part of the east face; but the southeast passage indicates 5½, 6 and 6½ fathoms, where it probably marks the southwestern extension of the eastern barrier reef, separating the lagoon from the southern plateau to the south of the encircling reef.

The western face of Manga Reva and of Tara Vai are indented by deep bays, which are formed by spurs running from the central ridge of these islands, the remnants probably of small craters which flanked the large crater, of which Manga Reva forms the western rim and Au Kena is the remnant of the southeastern edge, the former extension of this rim being indicated by the spits uniting the base of Mt. Duff with Au Kena; and by the projection of Au Kena towards the outer barrier reef, and of the numerous patches of coral reef off the northeast point of Manga Reva towards the outer line of motus until they almost unite with the barrier reef.

The western bays of Manga Reva Island are filled with fringing reefs which leave but here and there a deeper pass to the shore. The south face at the foot of the bluff of Mt. Mokoto and Mt. Duff is edged by a flourishing fringing reef, which extends nearly half a mile on the plateau at their base. The port of Rikitea is a reef harbor formed within the large fringing reef which occupies the whole of the southern bay of Manga Reva Island. The east face of Tara Vai and part of the east and of the west face of Aga-kanitai are also fringed with reefs.

The islets and the islands of Aka Maru, Mekiro, and Maka-pu are within a fringing reef flat which runs around the west face of Aka Maru; Au Kena is also fringed by an extensive reef which runs out in a spit of more than half a mile in a northeasterly direction almost to the outer line of motus, which are nearly united with it by these irregular patches. To the west of Au Kena a huge spit of 2 miles in length extends towards the base of Mt. Duff and almost unites with the fringing reef off the Cemetery, leaving a narrow but deep pass for the entrance of ships into the inner harbor of Rikitea. There is only 1 to 2¾ fathoms of water on these two spits.

The depth of the basin within this area with from 25 to 31 fathoms would be naturally explained as being part of an ancient crater, as in Totoya in Fiji; its northeastern rim is also perhaps further indicated by the comparatively shallow flat of the lagoon to the west of the barrier reef, with from 5 to 11 fathoms of water.

The principal islands of the group are in the central part of the lagoon. The four larger islands are Manga Reva, Tara Vai, Au Kena and Aka Maru. Tara Vai is flanked by Aga-kanitai and another islet to the west called Topunui; Aka Maru is flanked by Mekiro to the north and by Maka-pu to the south. The southeast face of Aka Maru is an extinct crater, of which Maka-pu forms the south rim. The main ridge of Tara Vai is the edge of parts of three craters now opening to the west. The four small volcanic islands in the southern part of the lagoon are isolated fragments, steep to, greatly weathered, and disintegrated. No soundings exist to show their relation to the other islands of the group.

The soundings thus far made indicate in the southern part of the lagoon a depth of about 23 fathoms, with an occasional hole of from 38 to 40, and a gradual slope towards the outer sunken reef. To the south of the old crater of Manga Reva the general depth of the bank varies from 6 to 11 fathoms, with a deeper channel varying from 20 to 40 from southwest of Au Kena towards Tara Vai. The lagoon seems to form a western basin where the depth varies from 10 to 20 fathoms.

To the west of Au Kena and Aka Maru, lying between them and the line of the outer barrier reef islets, a similar but shallower and flat basin exists, off the northern end of Manga Reva, between it and the northern horn of the barrier reef, with from 7 to 11 fathoms. Its rim is formed by a ring of reef patches of varying size.

On two occasions we visited the outer barrier reef and examined the outer line of islets of the eastern face of the Gambier Islands. The position of the islets as marked on the chart is not that of to-day, and the position of the reef flats is not accurate. The position of Tekava and Tauna appears to be correct. Opposite Au Kena and in its extension, the east face of the barrier reefs projects sharply to the east, forming an angular horn with one island south of the horn and the other north, running at sharp angles with it, so as to form a triangle which makes a deep bright opening westward to such an extent that when off the northern side of the horn we could see Tekava far to the westward of it. The second island is followed by a third and then by an island (Tarauru-roa) nearly 2 miles long; these are separated by small gaps. Then comes a larger island (Amou) followed by three small islands separated by deep gaps.

At Vaiatekeue (not the Vaiatekeua on the chart), the reef flat becomes quite narrow; it is hardly more than 100 yards wide; the islets perhaps 50. The northern islets are small and separated by long stretches of low shingle and carry but little vegetation and very few cocoanut trees. There are but two short sand beaches all the way from the northeastern to the eastern horn of the eastern face of the encircling reef of Manga Reva. A regular dam of shingle from 10 to 14 feet high, on the top of which the usual coral reef vegetation flourishes, extends along the outer face of the reef flat, which varies from 50 to 150 yards in width, and is flanked at the base by low buttresses of modern elevated coral reef rock and of breccia in places, all more or less weather beaten and honey-combed.

The islets and their formation and their junction or division into larger or smaller islets and the gaps which separate them, the mode of formation of the buttresses, of the planed-off, hard nearly level reef flat, of the coralline mounds of the outer edge,—all these differ in no way from what has been described in other barrier reef islands and atolls of the Pacific.

The beaches of the lagoon are steep, and corals do not seem to thrive in those parts of the lagoon to which the sea does not have access or at some distance from shore. This is well shown by the vigorous growth of corals in the fringing reef to the south of Mt. Duff on the outer edges of the reef patches of Port Rikitea, and on the spits which connect Au Kena with

Manga Reva, in contrast with those along the west face of the lagoon flats to the west of the eastern barrier reef.

There is a northeast horn of the eastern barrier reef in the extension of Manga Reva Island, forming the northern culmination of the central bight of the eastern face of the barrier reef. From that point the reef flat runs westerly to form the northern horn about 3 miles north of Manga Reva Island. The position of the outer reef cannot be correct on the chart (H. O. No. 2024). On leaving Manga Reva we made three soundings close off the reef flat line of breakers—one off Tekava, at the most ⅓ of a mile from the reef, in 225 fathoms. Our position, plotted by tangents to the volcanic islands or by their summits, indicated in this case, on the chart, a distance of 1½ miles. A second sounding of 245 fathoms off the eastern horn at less than ½ mile, indicated on chart No. 2024 a distance of 2 miles from the horn; and a sounding of 241 fathoms ¼ of a mile off the point which we had visited (Vaiatekeue) indicated a distance of ¾ of a mile on the chart.

The slope of the Gambier Archipelago to the east is steep. On coming in sight of Manga Reva we sounded in 2070 fathoms at a distance of 11 miles from Mt. Duff, that is, 6 miles from the outer edge of the reef bearing southwest; and on coming out we sounded again half-way to that point at a distance of 3¼ miles from the breakers in 1394 fathoms.

One cannot fail to be struck with the similarity of the Manga Reva Archipelago with the great atoll of Truk. If I remember rightly, Darwin also called attention to this from a study of the charts. Yet, owing to the great size of Truk, no less than 125 miles in circumference, and the great distance of the barrier reef from the encircled volcanic islands, the effect as one steams into Manga Reva is totally different from that produced by Truk. In the latter some of the islands, though large, and of the same height as those of Manga Reva, are much more scattered, and seem of comparatively small importance in the midst of the huge lagoon which surrounds them. The barrier reef islets of Truk are from 11 to 15 miles distant from the encircled volcanic islands. In Manga Reva, which is only 45 miles in circumference, after passing the small islands in the southern and open part of the lagoon when once off Maka-pu, we can fairly well take in the atoll as a whole. The western island (Tara Vai) is only 5 miles off; Manga Reva and Au Kena are about 3, as are also the islets of the east face of the barrier reef; these distances, as you approach the entrance to Rikitea, are constantly growing less, so that when in the gap between Manga Reva Island and Au Kena, at the foot of Mt. Duff, none of the larger islands are more than 3 miles off; and the islets of the eastern face of the barrier reef are seen to the northeast about 4 miles off. When on the summit of the central ridge of Manga Reva one can, in a radius of a little more than 4 miles, take in the whole panorama of Manga Reva, and get an impression of the relations of its different part far better than can be conveyed by the chart, for the whole of the visible part of the archipelago is included in a line drawn east and west, south of Maka-pu; south of that line the position of the southwestern reef can be traced only by the discoloration of the waters.

Manga Reva is an intermediate stage of erosion and denudation, between a lagoon archipelago such as Truk, and a barrier reef island like Vanikoro, and other islands in the Society groups such as Bora Bora,* Huaheine, Raiatea, Eimeo, in which the surrounding platform has comparatively little width and the barrier reef is close to the principal island and often becomes part of its fringing reef. Manga Reva is open to the south and to the west, Vanikoro to the east, while the volcanic islands of Truk are completely surrounded by the outer encircling barrier reef, as are the Society Islands just mentioned, which have several wide passages into the lagoon through the wide barrier reef.

One is tempted to reconstruct the Gambier Archipelago of former times and to imagine it with a great central volcano, of which Manga Reva and Au Kena are parts of the rim which once were connected from the southeast point of Manga Reva to Au Kena, and thence along the line of the outer islets to the northeast end of the former island with a deep crater of more than 34 fathoms. On the west face it was flanked by smaller craters extending to the western islets of the barrier reef, of which the bays of Taku, Kirimiro and Rumaru, and the bays of the west side of Tara Vai are the eastern ridges. There were probably also other secondary volcanoes, of which Aka Maru and the islets of the south part of the lagoon are the remnants, the latter all being situated on the gentle slope of the southern part of the Manga Reva plateau; this may have been the southern slope of the principal volcano of the group, on the face of which have grown up the outer lines of the barrier reef and its islets.

The existence of a large central volcano would readily explain the depth of the lagoon in its different regions, as well as the great depth off the outer face of Manga Reva, depths showing slopes which are no steeper nor more striking than the height and slopes of the southern part of Manga Reva or Tara Vai, of Aka Maru, and of Maka-pu, supposing them to be extended into the sea.

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*See A. Agassiz,—The Coral Reefs of the Tropical Pacific, Plates 210 and 231.

Mt. Mokoto and Mt. Duff drop precipitously for more than one-third their height and in less than a quarter of a mile fall from over 1300 feet to the level of the sea. Similar slopes are found along the volcanoes of Easter Island where there are no coral reefs. The edge of the crater of Rana Kao drops perpendicularly a height of nearly 1000 feet in less than one-eighth of a mile horizontal distance; and the eastern face of the crater of Rana Roroka rises vertically about 800 feet above the plain of Tangariki.

It is interesting to note how poor is the flora of the Manga Reva Archipelago as compared with that of the more western volcanic islands like the Marquesas and the Society Islands and some of the western elevated Paumotus. In the Gambier Archipelago the forests are reduced to a few patches extending along the small valleys of the slopes of the volcanic spurs. I am informed that even in the thirties of the last century, when the missionaries first landed at Manga Reva, the forest trees, while more numerous, yet never attained the luxuriance of growth that they attain in the Society and Marquesas Islands. At the present day, with the exception of the forest patches just mentioned and a few trees which have been introduced for cultivation, the islands of the group are in great part thickly covered with a species of cane closely resembling that of our Southern States. The fauna of Manga Reva is also extremely poor. There are no mammals, and with the exception of a "sandpiper" no indigenous birds. Sea birds are few in number, and in our trip in the Eastern Pacific we rarely had more than three or four birds accompanying us; often only one, and frequently none was visible for days. There are a few lizards on the islands, apparently of the same species as those in the Society Islands.

We left Port Rikitea for Acapulco on the 4th of February to anchor off Aka Maru; on the 5th we left our anchorage, sounded off the east face of Manga Reva, and took photographs.

On our way north from Manga Reva to Acapulco we did not begin to trawl or tow until warned by the surface nets that the surface was becoming richer in animal and vegetable life and also by the surface temperatures indicating that we had reached the southern edge of the cold western equatorial current. A little north of 10°, south latitude, we made our first haul and deep tow, and found a very rich fauna down to the 300 fathom line, recalling the pelagic fauna of the eastern lines and fully as rich. On trawling we found, as we expected, a very rich bottom fauna.

Among the animals brought up in the trawl there were some superb Hyalonemas, siliceous sponges, Benthodytes and other deep-sea holothurians, fine specimens of Freyella, and some large ophiurans. This haul is interesting as showing that in the track of a great current, with abundance of food, we may find at a very considerable depth (2422 fathoms) an abundant fauna at very great distances from continental lands. We were, at this station, about 2140 miles from Acapulco, 1200 miles from Manga Reva, 1700 miles from the Galapagos, and about 900 miles from the Marquesas.

Another haul made under the equator near the northern edge of the cold current in 2320 fathoms gave us the same results. The pelagic fauna was very abundant, the surface teemed with radiolarians, diatoms, and Globigerinæ and swarmed with invertebrates. The trawl contained a superb collection of bottom species of holothurians, Brisinga, Hyalonema, Neusina, and on this occasion we brought up the only stalked crinoid collected during this expedition—parts of the stem of two specimens of Rhizocrinus, of which, unfortunately, the arms were wanting.

Our progress, which was excellent during the first days of our journey after leaving Manga Reva, has for the past six days been greatly impeded by head winds in the region where we ought to have been in the full swing of the southeasterly trades. This led us to abandon with great reluctance all idea of further work in the equatorial belt of currents; to give up our proposed visit to Clipperton, and on account of our limited coal supply, to make for Acapulco, merely sounding every morning. This was a great disappointment to me, as we had every reason to expect to be able to spend some time in the region of the equatorial current's belt and settle more conclusively than we have been able to do the question of their influence upon the richness of the fauna living in their track far from continental shores or insular areas.

The presence of diatoms in all parts of the Humboldt Current, which we crossed from south of Callao to the equator at the Galapagos and west towards Clipperton, shows how far the track of a great oceanic current can be traced, not only by its temperature but also by the pelagic life within or near it. When once in the warm westerly equatorial current the diatoms disappear and the bottom samples show only surface radiolarians and Globigerinæ.

We took a number of serial temperatures in the line Galapagos to Manga Reva, passing from the colder water of the Humboldt Current to the warmer waters south toward Manga Reva. The temperatures at 200 fathoms became nearly identical. North the great change in temperature took place between 25 and 200 fathoms, where there was a difference of 24°. South the warm water extended 100 fathoms, a great change occurring between 100 and 200 fathoms, a drop of 16°. The serial temperatures taken at the southern and northern edges of the cold current on the line Manga Reva-Acapulco agreed well with those taken in the same current to the east.

The samples of the bottom obtained by the soundings taken by the expedition or gathered in mud-bag and in trawl indicate that an immense area of the bottom of the Eastern Pacific is covered with manganese nodules, and that they play an important part in the character of the bottom, not only in the area covered by this expedition; the area of manganese nodules probably extends to the northwest of our lines to join the stations where manganese nodules were found by the Albatross in 1899 in the Moser Basin, on the line San Francisco to Marquesas.

This area may also extend south of our lines Callao to Easter Island, and join the line west of Valparaiso where the Challenger obtained manganese nodules at many stations. I do not mean to imply that manganese nodules are present to the exclusion of radiolarians and of Globigerinæ. It is probable that the layer of nodules are partly covered by them, and by the thick, sticky, dark chocolate-colored mud which is found whereever manganese nodules occur.

During this expedition we sounded every day while at sea and developed very fairly that part of the Eastern Pacific which lies to the south and west of the line from Cape San Francisco to the Galapagos and west of a line from Galapagos to Acapulco, limiting an area occupied by the Albatross in 1891. The area developed by us is included by a line 3200 miles in length from Acapulco to Manga Reva and the area north of a line from Manga Reva to Easter Island and from Easter Island to Callao. We developed on our line Galapagos to Manga Reva the western extension of the Albatross Plateau, and found it of a depth varying from 1900 to somewhat less than 2300 fathoms in a distance of nearly 3000 miles; about half-way from the Galapagos to Manga Reva we came upon a ridge of about 200 miles in length with a depth of 1700 to 1055 fathoms, dropping rapidly to the south to over 1900 fathoms. I propose to call this elevation Garrett Ridge.

Our line from Manga Reva to Acapulco continued to show the western extension of the almost level bottom of the Eastern Pacific. In a distance of 3200 miles the depth varied only about 400 fathoms. This great area was practically a mare icognitum. Three soundings in latitude 20° south towards the Paumotus and five soundings in a northwesterly trend from Callao to Grey's Deep, are all the depths that were known previously of this great expanse of water. This existence of the great plateau dividing Barber Basin along the South American coast from Grey and Moser Basins to the west is most interest ing. It recalls the division of Southern Atlantic into an Eastern and Western Basin by a central connecting ridge, the Challenger ridge. The Albatross Plateau joins the western extension of the Galapagos Plateau as developed by the Albatross in 1891.

The existence of a sounding of 2554 fathoms near the equator in longitude 110° west would seem to indicate a small basin included in this plateau disconnected from Grey's Deep and Moser Basin by its extension to the west. How far west towards these basins that extension reaches, no soundings indicate as yet. It is interesting to note that along the Mexican coast there are a number of deep basins lying disconnected close to the shore just as there are a number of disconnected deeps close along the South American coast extending from off Callao to off Caldera, Chili, opposite high volcanoes or elevated chains of mountains. These basins and a great part of the steep Mexican continental shelf are deeper than the Albatross Plateau to the south, and form a deep channel, separating in places the Plateau from the steep continental slope. The steepness of the continental shelf is well seen, especially off Acapulco and Manzanilla. One of the small basins along the Mexican coast with 2661 fathoms lies off Sebastian Viscaino Bay; another with more than 2900 fathoms is to the west of Manzanilla Bay; a third to the southeast of Acapulco has about the same depth, and a fourth with 2500 fathoms is off San Jose, Guatemala. Our last soundings off Acapulco about 29 miles south of the lighthouse, in 2494 fathoms, showed the western extension of one of these deep holes to the east of Acapulco. These basins off the west coast, close to the shore at the foot of a steep continental slope, are in great contrast to the wide continental shelves which characterize the east coast of Central America and the east coast of the United States.

The collections made during the present expedition will give ample material for extensive monographs on the holothurians, the siliceous sponges, the cephalopods, the jelly-fishes, the pelagic crustaceans, worms and fishes of the Eastern Pacific, as well as on the bottom deposits and on the radiolarians and dinoflagellates, diatoms, and other protozoans collected by the tow nets. Small collections of plants were made at Easter Island and Manga Reva which may throw some light on the origin and distribution of the flora of the Eastern Pacific.

## ART. XL.—*Note on the Names Amphion, Harpina, and Platymetopus*; by PERCY E. RAYMOND.

AFTER my recent paper on the Chazy Trilobites (Annals Carnegie Museum, vol. iii, No. 2) was in type, Dr. W. J. Holland called my attention to the fact that the name *Amphion* was in general use for a common genus of moths. A little investigation showed that not only *Amphion*, but *Harpina* and *Platymetopus*, two other generic names used in the paper cited, were likewise preoccupied.

The first use of *Amphion* as a generic name was by Hübner, who, in 1816, applied it to one of the Lepidoptera.* Pander proposed the same term for a tribobite, in 1830,† and designated *Amphion frontiloba* = *Asaphus Fischeri* Eichwald as the type. Since *Amphion* is thus preoccupied, it becomes necessary to find some other name to apply to this trilobite. Angelin, in 1854,‡ used *Pliomera* as a new generic designation for trilobites of the type of *Asaphus Fischeri* Eichwald, evidently intending to restrict the genus to its original meaning. This name *Pliomera* should now be adopted to replace the preoccupied name *Amphion* Pander.

The Chazy species *Amphion canadensis* differs in several particulars from the European form *Pliomera Fischeri*. In the American species the median furrow of the glabella is very faint and frequently absent; the second pair of furrows are much further apart, thus producing one large frontal lobe instead of two small ones as in the Russian species; the facial sutures reach the lateral margin in front of the genal angles; the frontal border is not denticulate, and the two species do not have the same number of thoracic segments.

The absence of the median glabellar furrow and of the denticulate margin seem to be of considerable taxonomic importance, as this furrow cannot be regarded as due to the mechanical effect produced by the enrollment of the animal in pressing the spinose tail against the glabella. This is proved by the fact that no pygidial spine is situated opposite the median furrow, but that the two median spines of the pygidium are placed so that one comes on either side of the frontal furrow. Again, the second pair of glabellar furrows are longer than this median furrow, and the third set is still longer, as would be the case if all were glabellar furrows. Finally, in *Amphion canadensis* there is a smooth border around the front, and the median indentation is almost obsolete, while the pygidium is exactly similar to that in the European species. If this median indentation does represent the first pair of glabellar furrows, and *Amphion canadensis* has lost it and the denticulate glabellar margin as well, then *Pliomera Fischeri* denotes an earlier stage in the development, and it will probably be best to separate the American forms under the name *Pliomerops*, with *Amphion canadensis* as the type. *Amphion convexus* Billings and *Amphion Westoni* Billings appear to belong to this subgenus. In regard to *Amphion Barrandei* Billings states that a small median pit is present in exfoliated specimens,* indicating the presence of this median furrow in a rudimentary but deep-seated condition.

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* Verzeichniss bekannter Schmetterlinge.

† Beiträge zur Geognosie des russischen Reiches, p. 139.

‡ Palæontologica Scandinavica, p. 30.

The generic term *Harpina* was first used by Burmeister, in 1844, for a species of Coleoptera,† while Böck used it for a crustacean, in 1870.‡ Novák proposed the name a third time, in 1884, for a subgenus of *Harpes*,§ using it to designate the Lower Silurian forms of the genus. The hypostoma differs in the Upper and Lower Silurian species, and it was on this difference that the two genera were separated. The hypostomas of the Chazy forms are not known, but it is probable that they will be found to agree with those of the species from the Ordovician investigated by Novák. In any event, it is necessary to supply a new name in place of the preoccupied *Harpina*, and *Eoharpes* is herewith suggested.

*Platymetopus* was first used by Dejean, in 1829, for a species of Coleoptera,‖ and by Angelin, in 1854, for a subgenus of *Lichas*.¶ In 1902, Reed** saw that the name was preoccupied and suggested *Paralichas* to take its place. Unfortunately this name had been applied by White, in 1859, also for a species of Coleoptera,†† hence it will be necessary to give a new name for species of Division 3 of Schmidt, of which *Lichas lævis* Eichwald is the type.‡‡ For this purpose, *Amphilichas* is proposed, and should be applied to the Chazy species now known as *Platymetopus minganensis*.

**Paleontological Laboratory, Yale University Museum, March 23, 1905.**

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*Paleozoic Fossils Canada, pp. 288, 321, 322.

†Handbuch der Entomologie. ‡Overs. Dan. Selsk.

§Studien an Hypostomen der böhm. Trilobiten, No. 2, p. 4.

‖Species général. des Coléoptéres. vol. v, p. 815.

¶Palæontologica Scandinavica, p. 68.

**Quart. Jour. Geol. Soc. London, vol. lviii, pp. 62, 89.

††Ann. Mag. Nat. Hist., ser. 4, vol. iii, p. 284.

‡‡Rev. der Ostbalt. Silur. Tril. Mém. Acad. Imp. St. Petersbourg, ser. 7, vol. xxxiii, No. 1, p. 49.

## ART. XLI.—*The Bragdon Formation;*[*] by J. S. DILLER.

*Introduction.*—The Bragdon formation of Shasta and Trinity counties, California, was named by Mr. O. H. Hershey[†] and regarded by him as Jurassic. The first fossils found[‡] by my party tended to confirm his view, but later[§] upon structural grounds it was referred provisionally to the lower part of the Carboniferous. This called forth an article[‖] from Mr. Hershey maintaining at length his original views. Last summer other fossils were discovered in the Bragdon confirming its reference to the Carboniferous, and this article is intended to present the evidence.

*Lithological character.*—The Bragdon formation was designated by Mr. Hershey[¶] to include an extensive series of thin-bedded shales, sandstones and conglomerates lying some miles north and northwest of Redding in Shasta and Trinity counties, California. The dark, often black, shales in strata ranging from a foot to sixty feet in thickness alternate with thin beds of sandstone and conglomerate. The sandstones are usually normal although sometimes dark, hard, and flinty, like quartzite and occasionally tuffaceous, but as Hershey says, and I fully agree, "the conglomerates are the most characteristic portion of the series."[**]

They are generally composed in large part of black and gray pebbles of quartz with others of sandstone, shale and limestone. Generally they contain no igneous material, but in some places it becomes abundant. By weathering, the limestone pebbles disappear leaving holes upon the surface, thus giving to the conglomerate a peculiar porous aspect. The beds of conglomerate are usually less than ten feet in thickness, but sometimes attain a maximum of nearly fifty feet. Quartz and chert pebbles prevail in the smaller and finer beds and sometimes also in the larger beds where the pebbles are not over half an inch in diameter. As the beds become coarser pebbles of sandstone become most abundant, while those of limestone also generally increase in number and size.

The Bragdon conglomerate is most abundant along the Sacramento River. Much of it is fine but some of it is coarse, with one exception much coarser than that found elsewhere. It is best exposed three-fourths of a mile above Elmore and also half a mile above the mouth of Middle Salt Creek: in both cases upon the left bank of the river, and sandstone cobbles predominate. They are thoroughly waterworn, round and smooth, attaining at the first locality a maximum diameter of two feet although they are generally not over six inches. Limestone cobbles are less abundant, somewhat smaller and often fossiliferous, while pebbles and coarse sand chiefly of vein quartz and chert form the matrix between the larger fragments as well as the beds of finer conglomerate. Away from the river, coarse conglomerate is rare. It was noted on the divide, about one and one-fourth miles southwest of High Mountain, called also Nawtawakit Mountain, close to the eastern edge of the Bragdon, where the pebbles of gray sandstone weathering red are sometimes six inches in diameter and very hard.

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[*] Published by permission of the Director of the U. S. Geological Survey

[†] Am. Geol., vol. xxiv, p. 39, and vol. xxvii, p. 236.

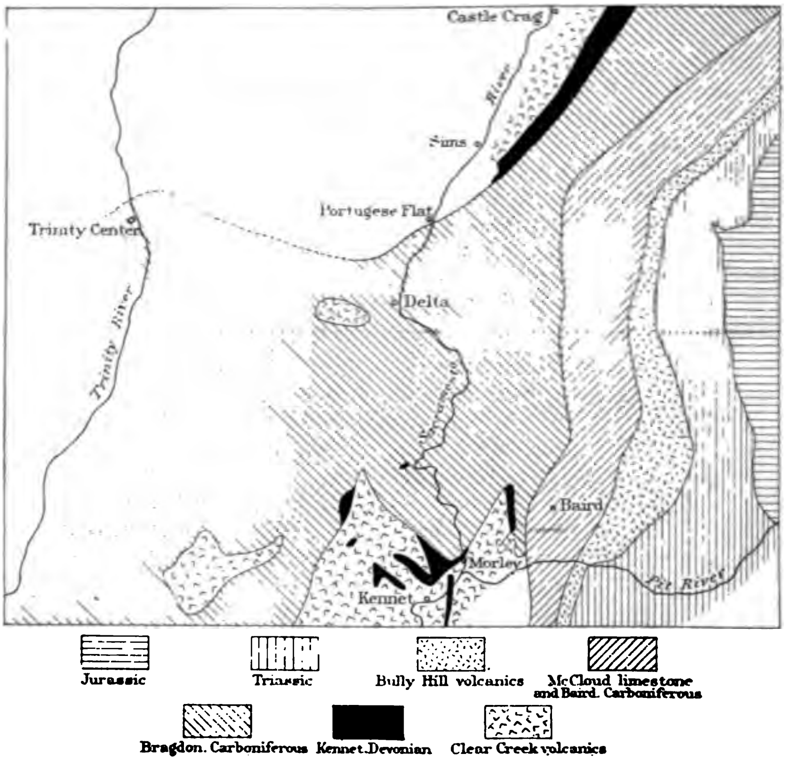
[‡] U. S. Geol. Survey, Bull. 196, p. 65.

[§] This Journal, vol. xv, p. 351.

[‖] Am. Geol., vol. xxxiii, pp. 248 and 347.

[¶] Am. Geol., xxvii, p. 236.

[**] Am. Geol., vol. xxxiii, p. 252.



Scale of map, 1 inch = nearly 7 miles.

*Distribution.*—The principal area of the Bragdon, and the one to which, excepting the western border, I have given special attention, is what Mr. Hershey calls the "eastern or type area."* As shown upon the accompanying map, it is roughly pear-shaped, constricted in the small part with the longer axis running nearly northeast and southwest. The bigger end lies near Trinity River from Lewiston to Trinity Center, while the smaller end is trenched by the Sacramento from Portugese Flat to Morley, and the long broad stem runs northeast from North Salt Creek to the McCloud, a total length of fifty miles and maximum breadth of about twelve miles. The borders are locally irregular and there are a few small outlying masses of Bragdon, but in general this area is remarkable for its continuity from the Trinity River to the McCloud without interruption excepting a small area of Devonian on Little Sugar Loaf Creek and small areas of volcanics on Clear Creek and Dog Creek, as well as several long narrow masses, not shown on the map, east of the Sacramento River. The smaller end of the Bragdon area, including the stem lying east of the Sacramento, is bordered on the one hand by the Carboniferous sediments and on the other by those of Devonian age; but west of the Sacramento, excepting a small bit on Backbone Creek, the type area of the Bragdon is everywhere bounded by igneous rocks, some volcanic, others plutonic. It is evident, I think, that the region of greatest promise in studying the taxonomy of the Bragdon is east of the Sacramento, where it comes in contact both above and below with sediments whose horizon is well established by an abundance of fossils. West of the Sacramento we are adrift among a plexus of igneous rocks whose exact age in most cases is not easily determined.

*Stratigraphy.*—The Bragdon, composed as it is of thin beds, lacks a definite rigid horizon to resist folding. It is easily crumpled, giving a great variety of dips and strikes. In the part of the area east of the Sacramento the dips are sometimes vertical, but for the most part not over sixty degrees, often under thirty and generally to the eastward, and agree fully with the general position of the Jurassic, Triassic and definitely known Carboniferous (McCloud and Baird), all of which lie to the eastward and increase in age westward, suggesting that the Bragdon is the oldest and lies beneath the Baird. This view is strengthened by an examination of the eastern limit of the Bragdon where it adjoins the Baird. The limit may be traced for more than twenty-five miles parallel with the Baird and McCloud limestone, within a mile or two west of the latter, and is marked by the disappearance of the characteristic Bragdon conglomerate. It must not be supposed that the same bed of conglomerate can be traced continuously along the eastern edge of the Bragdon for twenty-five miles. The conglomerate is in thin lenticular beds with traceable continuity of only a few miles, but farther along in the same horizon the conglomerate comes in again. This top horizon of the Bragdon will be noted at only two points. On Hirz Creek road the top conglomerate is fine, but west of it a few hundred feet is another that is coarse with fossiliferous Devonian pebbles. The strata are all nearly vertical and for the most part well exposed eastward to the shales full of Baird fossils. On the divide about a mile and a half southwest of High Mountain the characteristic conglomerates are well developed. Most of them are fine, but one is coarse, with many pebbles of sandstone and some of fossiliferous Devonian limestone. These lenses of Bragdon conglomerate are immediately and conformably overlain by sandstone containing Baird fossils. An observer cannot carefully study the contact of the Baird and Bragdon from one end to the other without being convinced on structural grounds alone that the Bragdon and Baird are conformable and that the former is the older.

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* Am. Geol., vol. xxxiii, p. 251.

As to the lower limit of the Bragdon, the matter is more complex owing to the fact that the basement on which it rests is variable, sometimes sedimentary rocks of Devonian age, but more frequently volcanics. The best exposure of the Bragdon resting on the Devonian is along Backbone Creek, three and one-half miles north of Kennet, where over 800 feet of Devonian shales and limestone* are overlain unconformably by a thirty-foot bed of Bragdon conglomerate containing fossiliferous Devonian fragments. To the east and west of this locality the Bragdon beds overlap the Devonian to the volcanics, but in both directions there soon appear other patches of Devonian lying between the Bragdon and the volcanics. Near-by, on Little Sugar Loaf Creek, a small area of fossiliferous Devonian is completely surrounded by Bragdon. Along this portion of the Bragdon border the small areas of Devonian are remnants left by pre-Bragdon erosion of a once continuous sheet of Devonian and thus exposing the volcanic rocks which lie beneath and were erupted before the Devonian sediments were deposited. To the northward, in the vicinity of Hazel Creek, the Devonian shales and limestone areas are more continuous and may be traced for over ten miles along the western border of the Bragdon. Although the contact is not well exposed, the fact that the basal conglomerates of the Bragdon are at least generally, if not everywhere, composed wholly of debris from the Devonian sedimentary rocks, clearly indicates an unconformity by erosion between them.

It is in this portion of the pear-shaped Bragdon area that its taxonomy is most evident and may be conveniently studied along the trails from the McCloud to Castle Crag and Sims on the Sacramento. The essential part of the McCloud-Sims section is given below, beginning with the newer beds on the east. The thickness given is only a rough estimate, making allowances for repetition by many small folds and faults.

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* This Journal, vol. xv, p. 347.

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|---|---|---|
| Carboniferous, | limestone, (McCloud) | 2000 |
| “ | reddish shales and sandstones with much volcanic material (Baird) | 1000 |
| “ | shales, sandstones and tuffs with siliceous conglomerates (of Devonian pebbles) increasing in number and size from the top towards the bottom (Bragdon) | 2900 |
| | (Unconformity) | |
| Devonian, | dark shale | 100 |
| “ | limestone | 150 |
| “ | black slaty shales (scarcely any chert) | 400 |
| ? | volcanic series | |

*Relation of the Bragdon to Volcanic Rocks.*—The Redding quadrangle contains an extensive series of highly fossiliferous sediments from the Devonian to the Tertiary inclusive, and affords one of the most complete records of the volcanic phenomena of that interval to be found in the state of California. This is not the place to enter into details concerning this record, and yet it is necessary to consider it very briefly in a general way to elucidate the relations of the Bragdon. Devonian sediments show the existence of andesitic and rhyolitic lavas of earlier date, and during the Bragdon and especially the earlier portion of the Baird there was considerable volcanic activity which continued for a long time and culminated about the close of the Paleozoic. A great sheet of lava and tuffs was formed at that time which appears between the Carboniferous and Triassic sediments. Volcanic eruptions continued at intervals throughout the Triassic and Jurassic but during the Cretaceous there was a long interval of quiescence, followed by the great eruptions of the Tertiary. It is not to be supposed that volcanic products were in all cases spread equally over the whole Klamath Mountain area for each volcanic horizon. The eruptions were local, yielding large masses at different places at different times, and to establish the horizon of each it is generally necessary to determine their relation to fossiliferous sediments.

Older than the Miocene, one of the largest among half a dozen horizons of volcanic products in the Redding quadrangle is that on the border of the Paleozoic and Mesozoic. The andesitic and rhyolitic lavas and tuffs of that horizon form a prominent ridge to which Bully Hill belongs, and the whole mass may be conveniently referred to as the “Bully Hill volcanics.” Concerning the age and structural relations of the Bully Hill volcanics, all observers practically agree in placing them about the close of the Paleozoic and the beginning of the Mesozoic, but as to the age of the large area of volcanics southwest of Bully Hill, along the Sacramento—the rocks which Mr. Hershey has called his Clear Creek volcanic series, I have but recently come to a definite conclusion. The generally complete absence of volcanic material in the typical Bragdon conglomerates, and also the fact that much of the igneous material which appears in the areas of "Clear Creek volcanics" cuts the Bragdon, for a long time counterbalanced in my mind the contention of Hershey that the Bragdon is younger than the "Clear Creek volcanic series" and rests directly upon it. But the discovery of andesitic and rhyolitic material like that of the Clear Creek series in certain Bragdon conglomerates well characterized by fossiliferous pebbles of Devonian limestone, leaves no doubt that in the main the "Clear Creek volcanics" near the Sacramento are, as Hershey maintains, older than the Bragdon.

On Backbone Creek, several miles above Kennet among the stratified rocks which appears to belong to the Devonian, there are definite beds of volcanic debris which indicate that andesites and rhyolites, like those of the "Clear Creek volcanics," were exposed to furnish Devonian sediments. The relation of the Devonian limestone and shales in the Kennet region to the "Clear Creek volcanics" confirms the same view. The Devonian sediments appear in patches completely surrounded by the "Clear Creek volcanics," at first suggesting that the Devonian sediments are broken up and enclosed by the volcanics. On closer examination, however, the isolated patches of Devonian are clearly seen to be, for the most part, remnants of a once continuous but deformed sheet of Devonian that covered the "Clear Creek volcanics" of that region, and was cut up by pre-Bragdon erosion into separate patches exposing larger areas of the underlying volcanics. A few miles northwest of Kennet the Devonian patches lie on ridges completely separated by the narrow canyon of Little Backbone Creek, but on Backbone Creek erosion has not yet quite completed the separation of the Devonian masses upon its sides.

The "Clear Creek volcanics" of the Kennet area which are beneath the Devonian, Mr. Hershey regards as on top of the Devonian. If his view were correct, they should lie between the Bragdon and the Devonian, which is certainly not true in the Kennet region where all three are well exposed, and in every Devonian outcrop touched by both Bragdon and "volcanics" the former is on top and the latter beneath. This relation is clearly exposed at two points on Backbone Creek, also on Little Sugar Loaf Creek, at the head of Bailey Creek, four miles west of Baird and near the mouth of Hazel Creek. It is evident, therefore, that the "Clear Creek volcanics" of Hershey in the Kennet region, being earlier than the middle Devonian, are not equivalent to the Bully Hill volcanics of late Carboniferous and early Triassic age. The fossiliferous tuffs and shales which are interstratified with the lavas of "Bully Hill volcanics," showing them to be of submarine eruption, are entirely lacking in the "Clear Creek volcanic series."

The general statements made in this paper apply only to the type areas of the Bragdon and of the "Clear Creek volcanics" east of Trinity Mountain, where it is believed their normal relations to Carboniferous and Devonian are better exposed than anywhere else in the Klamath Mountains.

*Age of the Bragdon.*—The Bragdon formation is regarded by Hershey as Jurassic about the horizon of the Mariposa, and he has set forth his evidence in detail.* It is in part lithological but largely structural, in which much stress in laid on the relative position of his "Clear Creek volcanics" regarded as of early Triassic age, but which, as I have already shown, are in part, at least, earlier than the middle Devonian.

Upon a geological map of portions of the copper belt of Shasta County, Anderson† represents the same rocks as Triassic, but the circumstances of publication did not permit him to present the evidence.

A study of the areal distribution of the Bragdon and its stratigraphic relation to the Carboniferous and the Devonian led me several years‡ ago to refer it provisionally to the lower part of the Carboniferous. Further field study has confirmed me in that opinion as already set forth. Fossils recently discovered support the same conclusions and will now be considered.

Mr. James Storrs, who has collected most of the fossils for my party of the Geological Survey in the Redding Quadrangle, early discovered that some of the limestone fragments of the Bragdon conglomerate are fossiliferous. Fossils have been collected at various times during four years from the conglomerate pebbles at twenty-one localities, chiefly along the Sacramento and to the eastward close up to the outcrop of the Baird formation, but also to the westward as far as Trinity Mountain and on the northwest to within a few miles of Trinity Center. These fossils were referred at first to Mr. Schuchert and later to Dr. Girty, and all of them as far as determinable, with one possible exception found on Bailey Creek to be mentioned later, were reported as Devonian like those already known in the region. The Devonian fossils in the pebbles simply show that the conglomerate is later than the Devonian.

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* Am. Geologist, vol. xxxiii, pp. 248-256 and 347-360.

† State Mining Bureau, Bull. 23, 1902, on Copper Resources of California.

‡ This Journal, vol. xv, p. 352.

Careful search was made in the paste of the conglomerate as well as in the associated sandstones and shales for fossils of the Bragdon epoch. Fossils were found in eleven localities, enumerated below, at six of which the fossils are in shales and sandstones, associated with the characteristic Bragdon conglomerate, while at the other five the fossils occur in the paste of the conglomerate, but not in the pebbles.

One of the most important occurrences is upon the divide southwest of High Mountain, where the sandstones conformably interbedded with characteristic Bragdon conglomerate contain shells which Dr. Girty reports as "Paleozoic, and without much doubt early Carboniferous, related to the Baird." The fossils, among which is a large "Spirifer of the Striatus type," occur in several beds. The exposures are good and leave no doubt that the fossils are of the Bragdon horizon.

Perhaps the most important locality is beside the railroad, one and one-half miles northeast of La Moine, where fossils were found in the sandstone adjoing the Bragdon conglomerate. From this locality Dr. Girty reports *Schizodus* sp., *Loxonema* sp., *Pleurotomaria* ? sp. and *Straparollus* aff. *S. luxus*. There is no room for doubt that these fossils belong to the Bragdon and are not derived from an older formation, and Dr. Girty remarks that if this be admitted "no other conclusion is possible than that the Bragdon is a Paleozoic formation. Indeed it is fairly safe to say that the horizon is not later than Baird, for the local faunas have many points of resemblance with that of the Baird, and none at all with those of the overlying Carboniferous formations."

From the shales about two and one-half miles southwest of the mouth of Hirz Creek, and also from shales in an isolated patch of the Bragdon about one and one-fourth miles a little east of south from Bayha, Cephalopods were collected. From the first locality Dr. Girty reports *Glyphioceras*, and from both a form "of what seems to be a *Nautiloid* to which Mr. Stanton recalls nothing similar in the Mesozoic and which is not out of place in the Carboniferous." Dr. Girty states further that "The little *Goniatite* shows only the course of the suture lines, external characters being concealed. The sutures remind me much of those of the *sphæricus* group of *Goniatites* (*Glyphioceras*), and if this is truly the relation of the specimen the age would probably be late Lower Carboniferous. Prof. J. P. Smith, who examined the specimen, on the other hand, thinks that it might represent an immature stage of an *Ammonite*. It seems to me, however, that an

Ammonitic stage sufficiently immature to show sutures of the simplicity of the present example would be of a size much smaller than it possesses. In my opinion, therefore, the specimen is a *Glyphioceras*, but the possibility should not be lost sight of that it may be a young stage of a more complicated and later developed type."

We now come to the fossils found in the paste of the Bragdon conglomerate. Dr. Girty identifies *Lithostrotion sublaeve*, a Baird species, from one and one-half miles east of Portugee Flat, and also on O'Brien Creek, one-fourth mile below the stage road. No other fossils were found at either place.

On Hazel Creek, six miles east of Sims, there is a conglomerate composed largely of volcanic material with but little chert and therefore not typical Bragdon. It includes what look like fragments of rotten calcareous sandstone which readily disintegrates, leaving very distinct and complete impressions of delicate parts of corals against the paste in such a way as to indicate, as pointed out by Dr. Girty, that the fossils are in place and not derived. Dr. Girty recognizes from this locality *Zaphrentis* sp. and *Loxonema* sp., and the last, if not both, appears to belong to the Baird.

The only case in which there is reasonable doubt concerning the relations of the fossils has already been referred to. It is on Bailey Creek, where a Bragdon conglomerate contains *Zaphrentis* and *Loxonema* ? in moderately soft sandstone having the form of a small pebble, while there is a suggestion in the arrangement of the fossils that, as on Hazel Creek, they are contemporaneous, yet the evidence is not clear. If it is a pebble, two explanations may be offered. There is the possibility and perhaps probability on the one hand that the forms mentioned may have begun in the Devonian, and from thence have been derived, or, on the other hand, that they may not be the identical forms of the Baird.

In estimating the weight of the evidence afforded by this one doubtful pebble containing more or less questionable forms, it is necessary to remember that the fossils in the sandstones and shales, as well as the matrix of the Bragdon conglomerate, point definitely to the conclusion that the Bragdon formation is Paleozoic and is fully in harmony with the stratigraphic evidence which places the Bragdon at the base of the Carboniferous section conformable beneath the Baird.

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *The Preparation and Properties of Tantalum.* — Metallic tantalum has been prepared by Berzelius, Rose, and more recently by Moissan, but always in an impure condition, either as a black powder, or, in Moissan's case, as a very hard, brittle substance containing carbon. WERNER VON BOLTON has recently succeeded in obtaining tantalum in a practically pure condition, and finds that it possesses some very remarkable properties which promise to make the metal one of great practical importance. Von Bolton has improved the processes of Berzelius and Rose (where a double fluoride is reduced with an alkali metal) and he has purified the product further by fusing it in a vacuum by means of the electric arc. He has also applied an interesting electrolytic process, consisting in passing an electric current through slender rods of the lower oxide in a bulb similar to that of the incandescent lamp, meanwhile pumping away the oxygen formed by the electrolysis as fast as it was formed. Pure tantalum when fused forms a brilliant regulus having a platinum-gray color, which can be hammered and drawn out into the finest wire. The specific heat is ·0365, and the atomic heat, 6·64, corresponds to Dulong and Petit's law. The specific gravity of the cast metal is 16·64. Its melting point was found to be 2250 to 2300°, and is far above that of platinum. It remains brilliant upon exposure to air, and oxidizes slowly when heated in air or oxygen. The metal shows an extraordinary combination of the properties of malleability, ductility, tenacity and hardness. For instance, when a red hot piece of tantalum is put under the steam-hammer, a plate of the metal is readily formed, which, when repeatedly heated and hammered, attains a hardness equal to the diamond. An attempt to bore such a plate one millimeter thick with a diamond drill with 5000 revolutions per minute had to be abandoned after three days and nights of continuous work, as a depression of only one-quarter millimeter was made thereby, and the diamond drill was much injured ; still the plate could be made thinner by rolling, without losing its hardness. Many applications are predicted for this most wonderful metal, one of which is the use of the wire for the incandescent lamp, in which it gives more than double the efficiency of the carbon thread.—*Zeitschr. für Electrochem.*, xi, 46. H. L. W.

2. *Gravimetric Determination of Nitric Acid.* — M. BUSCH has synthesized a base, diphenyl-endanilo-dihydro-triazol, named "Nitron" for the sake of brevity and for commercial purposes, which forms a very insoluble, stable nitrate, and, therefore, furnishes a means for the direct gravimetric determination of nitric acid, as well as for its qualitative detection. The reagent is manufactured on a commercial scale by Merck, and is employed

in the form of a ten per cent solution in five per cent acetic acid. For qualitative tests five or six drops of the reagent are added to 5 or $6^{ccm}$ of the liquid to be tested, after the latter has been acidified with a drop of dilute sulphuric acid. A white, voluminous precipitate appears immediately when considerable quantities of nitric acid are present, while with minute quantities of the acid small, brilliant, needle-like crystals are slowly formed. At ordinary temperature the reaction will detect one part of nitric acid in 60,000 of water, and it is still more delicate at 0°. Unfortunately, there are other acids which also give precipitates with the reagent, and thus chlorates, perchlorates, bromides, iodides, nitrites, chromates, sulphocyanides, ferro- and ferricyanides, picric acid, and oxalates interfere with the test.

To make the quantitative determination, the substance (containing about 0·1 g. of nitric acid) is dissolved in $80\text{–}100^{ccm}$ of water, ten drops of dilute sulphuric acid are added, the liquid is warmed nearly to boiling and $10\text{–}12^{ccm}$ of the previously mentioned solution of the reagent are added. The vessel is then allowed to stand 1½–2 hours in ice-water, the precipitate is filtered on a Gooch crucible and washed with a minimum quantity of ice-cold water. The precipitate is dried at 110° for three-quarters of an hour, and the calculation is made from the formula $C_{20}H_{16}N_4 \cdot HNO_3$, which contains only about one-sixth of its weight of $HNO_3$. Numerous test analyses, some of them made in the presence of NaCl, $CuSO_4$, and $AgNO_3$, show excellent results.

It appears probable that this method will find considerable practical application, for heretofore there has been no method for precipitating and weighing nitric acid.—*Berichte*, xxxviii, 861. H. L. W.

3. *The Unity of Thorium.* — Several years ago Baskerville announced that he had obtained fractions of thorium oxide showing varying specific gravities, which led him to believe that thorium was not a simple element; and in 1904 he advanced the view, based chiefly upon atomic weight determinations with different fractions obtained by volatilizing thorium chloride, that thorium contained three elements, berzelium, thorium (new), and carolinium, with atomic weights 212, 220, and 255, respectively.

R. J. Meyer and A. Gumperz have made a critical study of the volatilization of thorium chloride and of the atomic weight determination in such fractions, but they have been unable to find any evidence of the splitting up of our previously accepted thorium. They show that the method of determining the equivalent weight of thorium used by Baskerville was probably entirely unreliable (and was one which Krüss and Nilson, who have done the best work on this atomic weight, were also unable to use). They produced fractions of thorium chloride which should have corresponded to the so-called berzelium, etc., and obtained, by an accurate method of equivalent weight determination, perfectly constant results.

As further evidence of the unity of thorium, G. **Eberhard** has made a careful study of the arc spectrum of many samples of thorium material, including fractions made by a process of crystallization by the late Dr. Drossbach, fractions of the chloride by R. J. Meyer, and other preparations from thorite, fergusonite, yttrialite, and uraninite, and he has found no evidence that any separation of thorium into several components has taken place, or has even been begun. He concludes that the results of his observations show that any element different from the old thorium could be present in these samples only in very insignificant quantity.—*Berichte*, xxxviii, 817, 826. H. L. W.

4. *Nitroxyl Chloride.* — According to the results of several investigators, the acid chloride $NO_2Cl$ has been supposed to have been prepared, by the action of chlorine upon $NO_2$, by the action of chlorine upon silver nitrate, and the reaction of $NO_2$ with $PCl_5$. Other investigators have been unable to confirm the existence of this compound, and now **Gutbier** and **Lohmann** have made an elaborate series of experiments using all the suggested methods of preparation, and they have arrived at the conclusion that this "chloride of nitric acid" has not yet been produced.—*Jour. prakt. Chem.*, lxxi, 182. H. L. W.

5. *The Heusler Magnetic Alloys.*—These alloys consist of manganese, aluminium and copper; which under suitable proportions and conditions of temperature shows a magnetic state comparable with that of cast iron. E. **Gumlich** has made a careful study of two specimens of the following constitution:

| | | | | |
|---|---|---|---|---|
| 1. | Cu 61·5 per cent, | Mn 23·5 per ct, | Al 15 per ct, | Pb 0·1 per ct. |
| 2. | Cu 67·7 " | Mn 20·5 " | Al 10·7 " | Pb 1·2 " |

The magnetic measurements were made with cylindrical rods $18^{cm}$ long and $0{\cdot}6^{cm}$ diameter. Since the molecular conditions under changes of temperature promised to throw the most light upon this remarkable manifestation of magnetism in an aggregation of non-magnetizable metals, Gumlich submitted the alloys to a considerable range of temperature during the magnetic measurements. At the temperature of liquid air no marked change was observed. Considerable changes, however, ensued on raising the temperature of the alloys. With a field strength of $H = 150$ the flux of induction was noticeably greater in alloy 1, which contained the larger proportion of manganese and the smaller proportion of lead. The rods were submitted first to a temperature of 79° in alcohol steam for nine hours, and afterwards to 110° (melting point of toluol) for 27 hours. Rod 1 showed no marked change; but in the case of rod 2 there was a marked change of flux of induction, coercitive force, residual magnetism, and maximum permeability. L. Austin finds that the alloy resembles the magnetic metals in its volume-changes in a strong magnetic field.—*Ann. der Phys.*, No. 3, 1905, pp. 535–550. J. T.

6. *A High Frequency Alternator.*—W. **Duddell** describes an alternator which was primarily used in experiments on the resistance of an electric arc in which the interesting result was

obtained that this resistance with each increase of frequency behaved more like a solid resistance. The alternator was altered until the very high frequency of 120,000 cycles per second was obtained. The alternator was first driven by a figure of eight drive consisting of two bicycle wheels, one fixed direct to the motor shaft as the driving wheel, the other acting as a tension pulley to balance the pull on the alternator spindle. A surprising amount of power was required to drive the bicycle wheel at high speeds even without the inductor, and the author computes that the air friction on a single bicycle wheel running at 1200 revolutions per minute, or at a rim velocity of about 85½ miles per hour, required an expenditure of energy at the rate of about 200 watts; so that a cyclist to attain this speed would have to develop over one-half horse power to overcome the air friction on his wheels alone. The bicycle wheels were replaced by two phosphor-bronze discs, both being made drivers. The author describes his difficulties with belts. A cotton cord three-sixteenths of an inch in diameter gave the best results. In spite of every care all attempts to run the inductor at 1000 revolutions per second failed from the axis of inertia of the inductor not coinciding with its mechanical axis. If these axes were parallel and $1^{mm}$ apart, the pressure at 1000 revolutions per second on the two bearings would amount to 0·8 metric ton, which would be prohibitive on such small bearings. The inductor consisted of laminated toothed discs of iron which revolved between two pole tips provided with coils. A current of 0·1 ampere was obtained at a frequency of 120,000 per second. As an illustration of this high frequency the author remarks that in plotting curves for ordinary frequencies of 50 to 100 cycles per second the scale often adopted is 10 inches for 100 cycles. If it were attempted to plot a curve up to 120,000 cycles per second the paper would require to be nearly one-fifth of a mile long.—*Phil. Mag.*, March, 1905, pp. 299, 309. J. T.

7. *Deviation during Free Fall.*—It is still a question whether a southerly deviation of a freely falling body has ever been detected. De Sparre asserts that the formulæ usually given for easterly and southerly deviation during free fall are erroneous; for the variation in centrifugal force and the magnitude and direction of the weight are generally neglected. He gives mathematical expressions for the southerly deviation, according as the fall takes place in a well or from a tower. In any case the southerly deviation is too small for measurement, being less than $0·1^{mm}$ for a fall of $1^{km}$.—*Comptes Rendus*, cxl, Jan., 1905, pp. 33–35. J. T.

8. *Polarized Röntgen Radiation;* by Charles G. Barkla. (Abstract of a paper read before the Royal Society of London, Feb. 16, 1905.)—Experiments on secondary radiation from gases and light solids subject to X-rays showed that the character of this radiation differs only very slightly from that of the radiation producing it, and that the energy of this radiation is proportional

merely to the quantity of matter through which a beam of Röntgen radiation of definite intensity passes, being independent of the kind of matter.

These results, and the agreement between the energy experimentally determined and that calculated, led to the conclusion that this radiation is due to what may be called a scattering of primary X-rays by the corpuscles or electrons constituting the molecules of the substance.

On the hypothesis that Röntgen rays consist of a succession of electro-magnetic pulses in the ether, each electron in the medium through which these pulses pass has its motion accelerated by the intense electric fields in these pulses, and consequently is the origin of a secondary radiation, which is most intense in the direction perpendicular to that of acceleration of the electron, and vanishes in the direction of that acceleration. The direction of electric intensity at a point in a secondary pulse is perpendicular to the line joining this point and the origin of the pulse, and is in the plane passing through the direction of acceleration of the electron.

On this theory, a secondary beam whose direction of propagation is perpendicular to that of the primary, will be plane polarized, the direction of electric intensity being parallel to the pulse-front in the primary beam. If the primary beam be plane polarized, the secondary radiation from the charged corpuscles or electrons has a maximum intensity in a direction perpendicular to that of electric displacement in the primary beam, and zero intensity in the direction of electric displacement.

The secondary radiation from light substances was too feeble to allow accurate measurement of the intensity of the tertiary radiation.

A consideration of the method of production of primary Röntgen rays in an X-ray tube, however, leads one to expect partial polarization of the primary beam proceeding from the anti-cathode in a direction perpendicular to that of propagation of the impinging cathode rays, for there is probably at the anti-cathode a greater acceleration along the line of propagation of the cathode rays than in a direction at right angles; consequently in a beam of X-rays proceeding in a direction perpendicular to that of the cathode stream there should be greater electric intensity parallel to the stream than in a direction at right angles.

Such a beam was therefore used as the primary radiation, and the intensity of secondary radiation proceeding in a direction perpendicular to that of propagation of the primary beam from a radiator placed in that beam, was studied by means of electroscopes.

In the final form of apparatus the intensity of secondary radiation was measured in two directions perpendicular to that of propagation of the primary radiation and to each other, while the intensity of the primary beam was measured by a third electroscope.

Using paper, aluminium, or air as the radiator, as the bulb was turned round the axis of the primary beam studied, the intensity of a secondary beam was found to reach a maximum when the direction of the cathode stream was perpendicular to that of propagation of the secondary beam, and a minimum when these two were parallel, one electroscope recording a maximum rate of deflection when the other recorded a minimum. Many experiments were made which proved the evidence of partial polarization conclusive.

When heavier metals, such as copper, tin, and lead, which emit a secondary radiation differing considerably in character from the primary producing it, were used as radiators, no variation in intensity of secondary radiation was observed as the bulb was rotated. This result was not found to be affected by a considerable variation in the penetrating power of the primary radiation. Experiments were made with several X-ray tubes.—*Proc. Roy. Soc.*, lxxiv, 474.

## II. GEOLOGY AND MINERALOGY.

1. *Plans for Obtaining Subterranean Temperatures.* — The recently issued Year Book, No. 3 of the Carnegie Institution of Washington, contains a report by G. K. GILBERT of the progress made in developing plans for an investigation of the subterranean temperature-gradient by means of a deep boring in plutonic rock. Mr. Gilbert discusses in detail the importance of such an investigation and the conditions that should be satisfied in the solution of the place for the boring. The conclusion is reached that an altogether favorable locality for the work is to be found in the Lithonia granite district in Georgia. In regard to this region in its applicability to the object in view, the author says:

"In its general topographic character the Lithonia district is a plain. The stream valleys, for the most part open, are excavated to depths of 50 to 150 feet. A few rounded bosses of granite project from 50 to 150 feet above the plain. The granite is surrounded and in part overlain by schists, which appear to have originally constituted the walls and cover of the batholithic chamber. The continuity of the granite mass from outcrop to outcrop is inferred from the close lithologic similarity found at all the outcrops. This similarity includes not only composition, but a peculiar and unusual structure, the granite having an imperfect schistosity, the planes of which are everywhere contorted. It is therefore called by the State Geological Survey *contorted granite-gneiss.* The rock is massive. Only a few joints were observed, and these appeared to be occupied by thin veins, and thereby sealed, so as not to affect materially the continuity of the rock. The partings utilized in quarrying are parallel to the surface and are usually not natural, but created by blasting. They indicate a tendency toward exfoliation, which is one of the characters of massive granite. In recent studies in the Sierra Nevada I have found the tendency to develop partings parallel to the surface characteristic of massive rocks and absent from rocks traversed by systems of joints.

The extent of the granite body is not less than 10 miles in one direction by 3 miles or more in the transverse direction. Uniformity of character through such an area affords reasonable presumption that uniformity will be found in the vertical direction to such depths as are obtainable by the driller. The age of the batholith is not definitely known, but it is believed by students of Georgia geology to be probably pre-Paleozoic, and certainly not later than early Paleozoic. Of the later geologic history all that is demonstrated by the features of the locality is profound degradation, resulting in the development of a broad peneplain. Nothing is known in the vicinity of later orogenic or volcanic events, and the Cretaceous and Tertiary formations of the Coastal Plain are thought not to have covered this area. So far as is known, the region is one characterized by prolonged geologic quiet, and it has probably been exempt, as far as any locality which might have been selected in the United States, from physical and climatic accidents competent to disturb the arrangement of subterranean temperatures."

Besides the actual determination of the temperature-gradient, the conditions will be favorable for the prosecution of other investigations. The study of the core obtained would give valuable data as to the strength and physical properties of deeply buried granite. Further:

"It is at least worthy of suggestion that the boring could also be utilized for the subterranean swinging of a specially constructed pendulum, and the measurement of the earth's weight by means of a vertical pair of gravity determinations could thus be repeated. The homogeneity of the crust layer between the upper and lower stations and the representative character of the rock samples brought up as drill cores would be peculiarly favorable for the determination of the density of the crust layer.

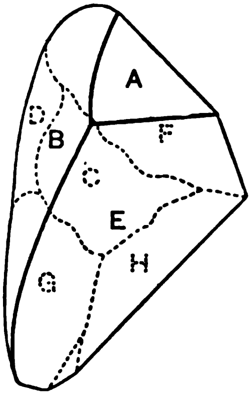
To give high precision to the determination of density it would be necessary to take account of the compression of the rock under stress of the superincumbent weight. Rock compression has not yet been measured in the laboratory, the matter being one of extreme difficulty, by reason of the deformation of both samples and testing apparatus when great pressures are applied; but there is reason to think that valuable observations bearing on this point could be made within the boring at some stage of the work. It should be possible, by suitable automatic appliances, to measure that resilient elongation of the column of rock constituting a section of core which theoretically takes place while the drill is separating it from the general mass. The importance to geophysics of experimental determinations of rock compression is generally recognized."

It is much to be hoped that it may prove possible to go forward with this most important investigation. The expense would be large, of course, but for a depth of 6000 feet not prohibitory; one estimate puts the cost of the boring at $110,000.

2. *Vermont Geological Survey;* G. H. Perkins, State Geologist. Annual Report, 1903–1904, 227 pp., 8 figs., 81 pls.—The fourth of the present series of Vermont State Reports indicates great activity on the part of Professor Perkins and his co-workers. In addition to a description of the present condition of quarry industries within the state, the report contains articles by Professor C. H. Hitchcock on the Glaciation of the Green Mountain Range, Professor V. F. Marsters on the Asbestos Deposits, and a paper by the state geologist on the Geology of Grand Isle County and the Brandon Lignite Deposit. Grand Isle County has been completely mapped in the past two years and the fossils have been studied. A special paper on the Stromatoceria of Isle LaMotte has been written by Professor H. M. Seeley. The origin of serpentine is discussed somewhat by Professor Marsters, who believes that magnetite may be shown to pass by imperceptible stages of decomposition into masses of fibrous serpentine. The interesting Tertiary deposits at Brandon are described and seven plates illustrating the fossil forms are published.

3. *The big "Cullinan" Diamond from the Transvaal.*—The April number of the Geological Magazine contains a description by F. H. Hatch and G. S. Corstorphine of the large diamond recently found in the Transvaal; from this we quote the following paragraphs. Two plates with four excellent views of the stone, natural size, accompany the paper but cannot be reproduced here.

"Great interest has been excited, not only in the Transvaal, but throughout the world, by the discovery at the Premier Mine, on Wednesday, the 25th January, 1905, of the largest diamond hitherto known. The stone was found by Mr. Wells, Surface Manager, in the yellow ground about 18 feet from the surface, a brilliant flash of light from a projecting corner having caught his attention. After a preliminary cleaning it weighs 3,024¾ carats. According to Gardner Williams the South African carat is equivalent to 3·174 grains; consequently the diamond weighs 9600·5 grains troy or 1·37 lbs. avoirdupois. Through the courtesy of the Directors of the Company, we have been enabled to make an examination of the stone, with the following result: It measures 4 by 2½ by 2 inches. The stone is bounded by eight surfaces, four of which are faces of the original crystal, and will be referred to in this description under the letters A, B, C, D, and four are cleavage surfaces, the cleavage being of course parallel to the face of the octahedron. In the following description these cleavage surfaces are referred to under the let-



Diagrammatic projection (to half scale).

ters E, F, G, H. They are distinguished from the original octahedral faces by greater regularity and smoothness. The shape and relative position of these various surfaces can be seen in the diagrammatic projection depicted in the text-figure, which has been drawn in the Mineralogical Laboratory of the Oxford University Museum, by the kind permission of Prof. Miers, F.R.S. The drawing is to half scale.

*Description of the Surfaces.*—A is an original octahedral face showing typical striations, the bands varying from 0·1 to 0·4 centimeter, and running parallel to the edge A–E. B is a large surface slightly curved showing partial striations, which, however, are interrupted by the slightly mammillary character of the surface. C is also a natural surface showing a few striations parallel to the edge C–E. D. Between B and F, C, G, there is an irregular octahedral face D, showing distinct equilateral triangular indentations which resemble etched figures, except in regard to their comparatively large size, the largest having a side measuring 0·7 centimeter. D is parallel to E.

E, F, G, H, are cleavage planes. E is the largest of these, and is a very perfect cleavage plane. Parallel to it within the crystal there is a small air layer between two internal cleavages, producing a 'rainbow' or Newton's rings. F is the second largest of the cleavage planes and shows a small spot within the crystal. G is an irregularly shaped cleavage plane. H is another cleavage face showing series of cleavages in the corner bounded by E and G. Two spots are visible, one actually on the surface, the other about 1$^{cm}$ within the crystal. Of the faces given, A and G, H and B, and E and D are parallel. In the case of B and H the parallelism is imperfect owing to the curvature of B.

The purity of the crystal is best seen on looking into face E, and the luster is well seen on the irregular natural face B, the broken cleavage on H causing a good deal of refraction which affects B to some extent as the facets of a cut gem would. For a large stone the crystal is of remarkable purity, and the color approximates to that of a blue-white.

The large size of the cleavage planes E and F indicates that a very considerable portion of the crystal is wanting. From the shape of B, D, and G, one can say that the entire crystal was irregular in shape, but A and D being octahedral faces, the presumption is that the complete crystal was a distorted octahedron, probably with dodecahedral faces developed on the edges. The portions missing probably amount to more than half of the original crystal.

The Cullinan diamond, as it has been named, after the chairman of the Premier Company, is more than three times the weight of the largest diamond previously known—the famous stone found in 1893 at Jagersfontein in the Orange River Colony, which weighed 972 carats.

4. *Moissanite, a Natural Silicon Carbide;* by GEORGE FREDERICK KUNZ.*—Professor Henri Moissan, at a meeting of the

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* Read before the New York Academy of Sciences, Jan. 9, 1905.

Academy of Sciences of Paris, held November 14th, 1904, read a paper on an examination made by him of a block of meteoric iron from Canyon Diablo, Arizona, which weighed 183 kilograms (403·6 lbs.).* Professor Moissan determined this mass to be somewhat heterogeneous in its structure, and to contain iron, nickel, sulphur, phosphorus, silicon and carbon. He found the latter element in its several forms,—amorphous carbon, graphite, and diamond,—and was able to separate both the black and the transparent variety of the diamond. He also discovered as absolutely new, in connection with these, green hexagonal crystals of silicon carbide. This is the substance which has been so extensively manufactured and sold commercially under the name of *carborundum*, and which, having a hardness of 9·5, above that of all minerals except the diamond, forms an admirable abrasive material for sawing gems, engraving glass, etc.

As this is the first instance in which this compound has been proved to occur in nature, and therefore, as a mineral, is entitled to a distinct mineralogical name, it would seem that the name of Professor Moissan himself should be associated with it. I would, therefore, propose for it the name of ***Moissanite***, as a slight recognition of his many services to chemistry, and especially of his researches on the artificial carbides and his study of the constituents of meteorites, and the reproduction of similar substances by means of the electric furnace.

Photographs made by Professor Moissan show that the specimens isolated were entire crystals and must have been formed in the meteoric mass itself; they were not fragments such as were found by an American investigator a few years ago associated with fragments of corundum, which upon a careful search of the material he learned had been ground into the meteoric mass from the abrasive used in sawing the meteorite. No saws were used by Professor Moissan with the mass examined by him.

5. *Occurrence of Palladium and Platinum in Brazil.* — A very full and interesting paper upon this subject is given by E. **Hussak** in vol. cxiii of the Sitzungsberichte of the Vienna Academy (Abth. I). An exhaustive summary of the historical data is followed by an account of the author's own extended observations.

The metal *palladium*, in the native state, was discovered by Wollaston in Brazil a hundred years ago, being identified with native platinum in sands from gold washings, probably at Conceicao. The author failed to find the metal in the platinum sands of this locality, but he proved that it did occur in irregular grains (not rolled) of dark gray to steel-gray color with platinum and palladium-gold in the highly auriferous "Jacutinga"† of the itabirites of Itabira do Matto Dentro, Minas Geraes.

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* Comptes Rendus, cxxxix, No. 20, cxl, No. 5, p. 277; also Chem. News, Dec. 14, 1904, Feb. 24, 1905: this Journal, xix, 191, 323, 1905.

† The name "Jacutinga" is given to the narrow layers and bands, hardly 50$^{cm}$ in thickness, that occur interbedded conformably within the itabirite (a quartz-hematite rock of schistose structure). The Jacutinga are often enormously rich in gold, which may be nearly absent from the surrounding itabirite.

*Palladium-gold*, an alloy of the two metals in varying proportions, is not uncommon and the scales of "white gold" belonging here were noted as early as 1700 though at first supposed to be silver.

It occurs in the gold washings at various points in the states Goyaz and Minas Geraes. It is also found, with native platinum in the rock itself, thus in the "Jacutinga" at the Gongo Socco mine near Caethe Minas, at Itabira do Matto Dentro and at Maquine near Villa Marianna. It also occurs at Candonga, Minas Geraes, in a pyroxene rock which is probably derived from a limestone by contact metamorphism. This rock forms layers in the itabirite.

*Platinum* has been known to exist in Brazil for about one hundred years, but, previous to the identification of palladium, it was often confounded with the alloy palladium-gold. The explorations and investigations of the past thirty years have added largely to the number of localities of native platinum, which may be summarized as follows:

(*a*) It occurs sparsely disseminated through the highly auriferous Jacutinga, interbedded in the itabirite, as at Gongo Socco.

(*b*) In the auriferous quartz veins of the crystalline schists on the Rio Bruscus, Pernambuco.

(*c*) Associated with the less frequent diamond and probably derived from quartz conglomerates, on the east slopes of the Serra do Espinhaco from Itambe do Matto Dentro to Itambe do Serro.

(*d*) In the Rio Abaete and its left tributaries, here probably derived from olivine-rocks as in the Urals.

It is noteworthy that the platinum of occurrences (*c*) and (*d*) varies widely in composition; that of Conceicao is non-magnetic and free from palladium with a specific gravity of 20·5; that from Condado is non-magnetic and rich in palladium, and that of Abaete is strongly magnetic and free from palladium, but rich in iron. The specific gravity of the platinum from Condado is from 15 to 15·5. The specific gravity of the metal from Abaete could not be determined because it was impossible to obtain the fine powder free from gold and perovskite.

In the occurrences (*a*), (*b*) and (*d*) the platinum seems to be a primary constituent, but in the remaining case, where it accompanies the diamond, it has so peculiar a form that a secondary formation is thought probable. Here the platinum appears not as rolled grains but in hollow forms, sometimes fern-shaped, with thin walls and mammillary or botryoidal, non-crystalline, surface; the structure is both concentric and fibrous. These forms are so unusual that a possible secondary origin is suggested, perhaps a deposit from solutions derived from the decomposition of sulphides carrying platinum. Such a formation the author regards as quite possible, since in the United States and Norway, ores of this kind (pyrrhotite, covellite, chalcopyrite) have been shown to carry platinum and to be associated with sperrylite ($PtAs_2$).

6. *Platinum Resources in the United States.* — The Geological Survey has undertaken the investigation of the resources of plati-

num in the country, having issued a circular giving information as to the nature and occurrence of the metal, and instructions as to sending samples, especially of heavy sands from placer mines, to Washington for thorough examination. A list is also given of the various localities, chiefly in California, Oregon, Canada and South America, in which platinum has been discovered, with indications as to which regions offer the most promise. It is to be hoped that this effort will result in developing the supply of the metal which is so much needed.

7. *Beiträge zur Mineralogie von Japan ;* herausgegeben von T. WADA. No. 1. Pp. 1–21. Tokio, 1905.—The recently issued volume on "The Minerals of Japan" by T. Wada was noticed in the January number. The same author has also undertaken the publication of a series of contributions to the mineralogy of Japan, of which the first number is now in hand. This contains an interesting account by Kotora Jimbo of crystals of *danburite* of Obira, Bungo Province, with list of forms observed and angles measured. Another paper by the same author describes the *siliceous oolite* of Tateyama, Etchū Province. This oolite either consists of loose colorless spherules of opaline silica or forms a loosely coherent mass of colorless or gray spherules cemented by partly anisotropic colorless opal, or opal mixed with decomposed rock particles; the spherules are also found in loose form. Microscopic examination shows a concentric structure with a series of rings. These rings are in part nearly structureless and isotropic, in part fibrous and doubly refractive; the fibers are negative ; between crossed nicols a black cross is obtained. The hardness of the spherules is about 6, the specific gravity nearly 2. They contain 93 per cent $SiO_2$ and about 4 per cent loss on ignition. After ignition more than 80 per cent of the powder is dissolved in four hours in KHO with eight parts of water.

The deposit described occurs in connection with the small crater-lake of Shin-yu, 70 miles in diameter, and not far from the well-known hot springs of Tateyama. The lake is now filled with hot, gray, turbid water, from which abundant gas-bubbles issue ; formerly the water is stated to have been cold.

The occurrence is one of much interest, since, as remarked by the author, it is the modern equivalent of the ancient springs of Pennsylvania described by various authors, among them Barbour and Torrey, see this Journal, xl, 246, 1890, also Wieland, ibid., iv, 262, 1897 ; the latest investigation is by Diller, Bull. U. S. G. Surv. 150, p. 95, 1900. The spherules of Tateyama differ from those of Pennsylvania in their lower specific gravity, their less crystalline appearance and greater solubility in caustic potash.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The spring meeting of the National Academy was held at Washington, April 18 to 20.

Five new members were elected at the meeting: Arthur A. Noyes, Boston, Mass. ; Michael I. Pupin, New York City; John

C. Branner, Stanford University, Cal.; William H. Holmes, Washington, D. C.; William H. Howell, Baltimore, Md.

The following foreign associates were also elected: M. Henri Becquerel, of Paris, and Prof. Dr. Paul Groth, of Munich.

The list of papers presented is as follows:

EDWARD L. NICHOLS: The mechanical equivalent of light.

Dr. H. C. WOOD and Dr. DANIEL M. HOYT: The effects of alcohol upon the circulation.

ALEXANDER AGASSIZ: The expedition of the U. S. Fish Commission Steamer "Albatross," in charge of Alexander Agassiz, in the Eastern Pacific, Lieut. Commander L. M. Garrett commanding.

WILLIAM M. DAVIS: Resequent valleys. The geographical cycle in an arid climate.

W. W. CAMPBELL: A catalogue of spectroscopic binary stars.

C. D. PERRINE: Discovery of the sixth and seventh satellites of Jupiter and their preliminary orbits.

W. K. BROOKS: The axis of symmetry of the ovaria egg of the oyster.

2. *Astronomical Observatory of Harvard College.* — Recent publications include the following:

ANNALS. Vol. LVI, No. II, Stars having Spectra of Class B.

Vol. LVIII, Part I. Observations and investigations made at the Blue Hill Meteorological Observatory, Massachusetts, under the direction of A. Lawrence Rotch. This part, of 62 pages, is devoted to a discussion by H. HELM CLAYTON of the diurnal and annual periods of temperature, humidity and wind-velocity up to 4 kilometers in the free air and the average vertical gradients of these elements at Blue Hill. Among other points of interest, it is shown that there is a rapid increase in wind-velocity from the ground to 500 meters, the rate being about twice as great in the night as in the day. From 500 up to 1000 meters, there is a slow increase in wind-velocity during the day but, in the average, a decrease by night. Above 1000 meters there is a steady increase of wind-velocity and the rate grows larger with increasing height.

CIRCULARS: No. 86, The nebula of Orion. No. 87, The ninth satellite of Saturn. No. 88, A new Algol variable −15° 4905. No. 89, The November Meteors of 1904. No. 90, 105 new variable stars in Scorpius. No. 91, 16 new variable stars in Sagittarius. No. 92, Stars having peculiar spectra.

3. *The Journal of Agricultural Science;* edited by R. H. Biffen, A. D. Hall, T. H. Middleton, T. B. Wood, in consultation with W. Bateson, J. R. Campbell, W. Somerville. Vol. I, Part I, pp. 1–148. January, 1905. Cambridge (The University Press). —This new journal has been recently started to give an organ for the presentation and discussion of scientific papers bearing on agriculture. It is proposed to issue the Journal as material accumulates, in parts of about 100 royal 8vo pages; a volume will contain four parts. Subscription ($4.50, single numbers $1.50) may be made to the Macmillan Co., New York City.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

## ART. XLII.—*On a Group of Visual Phenomena depending upon Optical Errors of the Human Eye;* by CHARLES S. HASTINGS.

IN two preceding articles* the writer has contributed measurements which serve to define the average human eye, both with respect to its color error and its error of collimation, to a closer degree of approximation than that of Helmholtz and his successors as embodied in the well known *schematic eye.* The aim of this paper is to discuss certain consequences which may be based upon these more exactly determined data and to describe, and explain as far as practicable, a number of visual phenomena not thoroughly studied heretofore, or, perhaps, wholly known. For this purpose we require, in addition to the elements established in the papers cited, a knowledge of the positions of the external and internal pupils of the model eye. By the former term is meant the virtual image of the real pupil as formed by refraction at the cornea; and by the latter, the virtual image of the real pupil as formed by successive refractions at the anterior and posterior surfaces of the lens. These are evidently so related to each other that a ray from an object outside to a point in the exterior pupil will correspond to a ray from the corresponding point in the interior pupil to the image of the object. If we take, as in the preceding articles, the vertex of the cornea as the origin of coördinates, together with the place of the center of the real pupil as established in the second paper, a simple calculation shows that the centers of the pupils are at $0{\cdot}3046^{cm}$ and $0{\cdot}3705^{cm}$, respectively, both lying on the nasal side of the axis of symmetry and approximately midway between these axes and the axes of vision. These values are for wave-lengths of mean refrangibility, the variations in the values for different wave-lengths not being of moment for our present purposes; the small difference in relative size of the two pupils is also ignored as immaterial.

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* This Journal, vol. xix, p. 205 and p. 310.

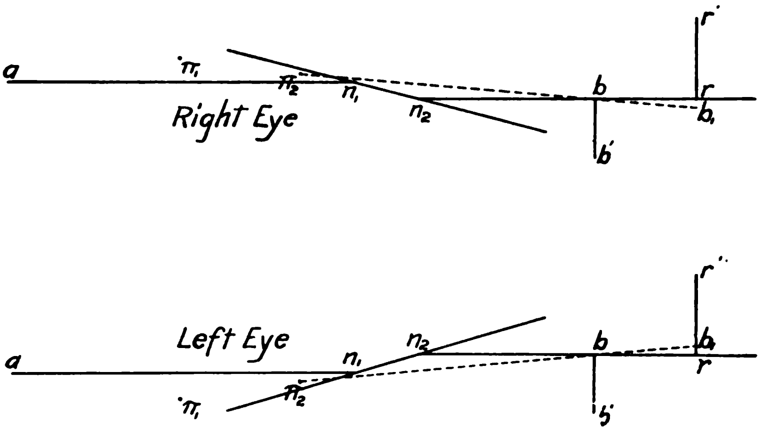
The elements of the schematic eye, so far as they are necessary to our investigation, are:

$a = 4^\circ{\cdot}2$
Dist. $\pi_2$ to $n_1 = 0{\cdot}3264^{cm}$
" $n_2$ to retina $= 1{\cdot}55^{cm}$

Dist. $\pi_1$ to $\pi_2 = 0{\cdot}0659^{cm}$
" $n_1$ to $n_2 = 0{\cdot}0357^{cm}$
" $F_b$ to $F_r = 0{\cdot}0566^{cm}$

These elements are represented in fig. 1, in which, for the sake of perspicuity, the scale is greatly distorted by increasing those of the first column in the ratio of 2·5 to 1 and those of the second column in the ratio of 25 to 1. With this qualification fig. 1 represents accurately the necessary elements of a pair of normal eyes, the lines $n_1 n_2$ being the axes of the eyes, the lines $a\ n_1$ the external, and $n_2 r$ the internal lines of vision, and the points $\pi_1$ and $\pi_2$ the positions of the centers of the external and internal pupils, respectively. The points $b$ and $r$ are the positions of the images of a distant object on the line of vision for two wave-lengths of light corresponding to a difference of refrangibility in water of ·0100, which corresponds to an interval in spectral colors nearly equivalent to that separating C and G.

1



### I. *Utility of Error of Collimation.*

Suppose both eyes directed to a distant surface divided vertically into two portions of which the left side is red and the right blue, the point of fixation for each eye being on the line of demarcation. In this case the image of the red surface would be represented by the line $r\,r'$ in each eye and that of the blue surface would be represented by the lines $b\,b'$, If the eyes were sharply focussed for red light, that is, if the retinas corresponded with the surfaces $r\,r'$, the observer would have a sharply defined image of the boundary in red and an ill-defined image in blue as the resultant effect of the diffusion circles due to the chromatic aberration of the eye. The diameter of these diffusion circles will bear the same ratio to the diameter of the interior pupil as the distance $b\,r$ does to $\pi_2 b$, while the centers of these diffusion circles corresponding to points at the boundary between the colored fields will lie on a line on the retina which is represented in the diagram by the projection of this line, namely, by the point where the line $\pi_2 b$ extended intersects the retina. It is obvious from inspection that only from the line $\pi_2 b_1$ towards the nasal side in the right eye, and towards the temporal side in the left eye, do we have a full illumination of the retina equal to that of the blue field itself. We see, therefore, that in the case supposed there is a narrow region, relatively dark, bordering the sharply defined edge of the red image in the right eye, while in the left eye there is a corresponding region where the contrast is reduced by a commingling of the two colored lights.

It is easy to see that if the eye is adjusted for distinct vision of the blue surface, that is, if the retina corresponds to $b\,b'$ of the diagram, exactly the same conditions as regards sharpness of distinction hold as before. If the observer's attention were directed to this particular feature of the object, that is, to the dividing line in the field, he would inevitably accommodate either for the red or for the blue, and, ignoring the confused sensation of the left retina, recognize a sharpness of division which would be lacking if the right eye were symmetrical in construction. If the red and blue fields were interchanged the left eye would become the discriminating one.

Before we can attach great importance to this conclusion we must see if the relations quantitatively considered are such as to support it. To do this we must calculate the angular width of the darkened strip and of the radius of the diffusion circles; the first giving us a notion as to its conspicuousness as an interruption in the field of vision, and the second a notion as to its intensity. We read at once from the diagram that the true width of the region is—

$$\left\{ (n_2-n_1)tg\,a+(\pi_2-n_1)tg\,\tfrac{1}{2}a \right\} \frac{br}{\pi_2 b} .$$

If this quantity be divided by the distance from $n_2$ to the retina, we shall have its angular width. This is found to be equal to 1′, a conspicuous magnitude, since alternate bright and dark lines of half this angular width can be distinguished under favorable circumstances.

The second part of the problem is not quite definite because the radius of the pupil is not a constant; but if we assume a diameter equal to $0{\cdot}2^{\rm cm}$ we shall be near the true value for ordinarily bright illumination. This assumption gives 6′·8 for the angular value of the radius of the diffusion circles; in other words, this is the angular width of the strip within which the illumination of the retina by blue light falls from its maximum to zero. As experiment shows that a diminution of luminous intensity of less than one per cent is obvious at a sharply defined border, there is no room for doubt that the peculiarity of construction does possess a useful function in vision, inasmuch as that with the established collimation errors we are enabled to detect boundaries of colored fields with a degree of precision which would be wanting in eyes without such errors.

This is a highly interesting reason for the persistence of a systematic optical error in the human eyes which is otherwise extremely difficult to account for, since no other possible error admits of correction so easily. If we recognize the advantage which the peculiar relation of the collimation errors in the two eyes gives to one searching for colored fruits or colored animals, we may be led to the conclusion that in an earlier state of racial development the peculiarity would have been more important than at present, and then, perhaps, to speculation as to whether it may not now be regarded as largely vestigial. This last idea would doubtless find support in the extraordinary irregularity of the constant of collimation in the sixty or more cases recorded.

## II. *Geranium Phenomenon.*

This is a name given provisionally to a peculiar visual phenomenon with which I have been familiar for an indefinite time, although it does not seem to have ever been noted, or at least recorded, by other observers. It is not unlikely that relatively few persons are able to see it, but it is not a personal peculiarity. Briefly described the phenomenon is this: Whenever I look at red geranium petals, in the brilliant light of out of doors, projected against the more remote background of its green leaves, the petals seem—in portions of the visual field at any rate—to be bordered with an exquisitely fine line of intense blackness, much more intense than that of black velvet under the same illumination. My eyes cannot make these black lines point of fixation for they are singularly elusive, but they are too delicate to be seen if they did not fall very near the axis of vision. Red petals of other flowers exhibit quite the same phenomena, notably red nasturtiums, but only strikingly when the green background is sufficiently luminous.

The more important general conclusions from such observations seem to be embodied in the following list:

(*a*) The phenomenon is monocular.

(*b*) The dark lines are conspicuous only when the illumination is intense (equals, probably, when the pupillary aperature is small).

(*c*) The contrasting colors must be well separated as regards refrangibility and of approximate equal brightness.

(*d*) The difference of the distances of the two colored fields from the eye must not be small compared to the distance of the nearer one.

By attention to these precepts I have been able to observe the same phenomenon with a considerable range of pure spectral colors as well as to prove that the order of the colors, as measured from the eye, is not essential. The reason that I see the black lines as described above, and no black border to a green leaf projected upon a red petal, is to be ascribed, probably, to the fact that my slightly myopic eye can form a sharp retinal image of the red when not more than one or two meters distant, while the green leaf would be notably out of focus.

A highly probable explanation of this phenomenon can, I think, be found from an inspection of fig. 1 above. Suppose the parti-colored object be shifted so that the line of demarcation falls on the line $n_1 \pi_1$ extended; then, in the right eye, $r$ and $b_1$ will have approached each other, but will still be distinct. Now imagine the blue portion of the object carried a considerable distance farther from the eye on the line $n_1 \pi_1$ extended, then light from points in the blue object very near its edge will send light to only the outer, or temporal, half of the pupil, the inner half being shaded by the nearer red object. It is, however, just this latter half of the pupil that transmits the light which diffuses blue light on the temporal side of the line $\pi_1 b_1$, hence there is a region of the retina between $r$ and $b_1$ in the right eye, upon which, under the conditions considered, no light falls on any color whatever. No doubt such an unilluminated portion of the retina, if it caused any visual perception, would be interpreted as a line of more than absolute external blackness.

In the case of the model eye the breadth of the dark band would be considerably less than one minute of arc and at a distance of about two degrees from the point of most distinct vision, hence it is perhaps doubtful whether it could be perceived as a black line. In the case of my own eyes the constant of collimation is about half that of the normal eye and the pupils are nearer the axis of vision. From these data we may estimate the angular value of $r\ b_1$ for my eyes, as something less than one half minute of arc at the *fovea centralis.* The value for the interval red-green may be regarded as half this value; and finally, at the eccentric position where the strip on the retina is wholly unilluminated this must be again reduced by an amount which could be determined accurately only when the constants of the eye are known with a greater precision than now attained. It is probable, however, that this value would not be less than ten seconds of arc. Whether a strip of the retina of a width only one sixth of the ultimate perceptual elements of vision would, when deprived of light, give rise to a conspicuous sensation, is a question which, as far as I can find. has not been considered by investigators in this field. It has been abundantly proved that the ultimate precision of optical definition, under the most favorable circumstances, is not less than 60″; on the other hand, there is obviously no minimum limit for the angular width of a bright line for visibility, since this is only a question of the amount of light received by the eye, or of its brightness. But the question of how narrow a black line on a bright field can be seen is wholly different. My own experiments, although of great simplicity, seem to be perfectly adequate for our present purposes. I found that I could see a black hair of a measured diameter of 0·0025 inch as a black line, against a sky of favorable brightness, up to a distance of 300 inches. At the greatest distance the angular width is only 1″·72. There is, therefore, no difficulty in adopting the above explanation of the phenomenon under discussion even if we were obliged to assume a much smaller value for the area of unilluminated retina.

A familiar example of this same phenomenon, if I am not mistaken, is presented to us by the appearance of a red billiard ball on a green table. Here the vertical contours of the ball are astonishingly sharp as compared to that of the upper surface, and also to what we might expect from the pronounced chromatic aberration of the eye.

### III. *Phenomenon of "Fluttering Hearts."*

This phenomenon, upon which much has been written, is thus described by Helmholtz:*—"A peculiar phenomenon, which perhaps belongs in the same domain as that of the flickering rotating disks, is that of the so-called fluttering hearts. On a colored sheet of stiff paper are placed figures of another vivid color; red and blue seem to yield the best results—the colors must be very vivid and saturated. If one looks at the sheet while it is moved to and fro with a certain quickness, the figures seem to move themselves and to shift forwards and backwards on their support. The cause of this appearance seems to depend upon the fact that the visual impression for different colors does not originate and die out with equal quickness, and consequently the blue appears left somewhat behind the red in the path described by the sheet."

Numerous experiments with a considerable number of observers made in accordance with this description proved wholly futile. Small disks of vividly colored paper scattered upon strongly contrasting grounds were tried under greatly varying circumstances of illumination and of observer without once succeeding. It was only after one of my colleagues brought me a particular book having green and black lettering printed upon a red cover, both colors being nearly saturated and of approximately equal luminosity, that the real phenomenon could be observed by me and exhibited to others. Even in this case it could not be recognized in a good illumination, either by day light or by artificial light, when the lighting was such that the texture of the surface and outlines of the green letters was well seen; but when illuminated by a single source of light, sufficiently remote so that the sharpness of the green letters was lost, the effect became absolutely startling—the green letters appearing to slip about among the black in a most unaccountable way. The astonishment shown by all to whom I have exhibited this optical illusion is a sufficient proof of its rarity in ordinary experience.

The indicated conditions of success in the experiment seem to be these:—

(*a*) The saturated colors must differ widely in refrangibility and not too widely in luminosity.

(*b*) The position of one of the colors in the visual field must be well determined—as by the sharply printed black letters in the object described—while the other must have its outlines ill defined.

With attention to these precepts I have been able to secure the illusion invariably with every one with whom I have experimented. By isolating small pieces of colored paper by a black border from the red background I have been able to show the peculiar shifting in question for various hues of green, blue, and ultramarine blue. Sometimes when not obvious to direct vision it becomes striking to averted vision.

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* Helmholtz, Physiol. Opt., 2te Aufl. p. 533.

The explanation, it seems to me, may be found in the differing angular velocity with which the images of different colors move over the retina. This difference can be readily calculated in the following method.

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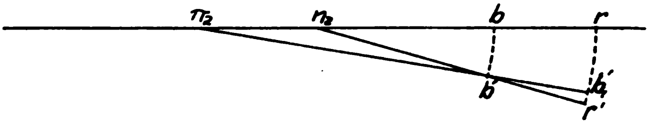

Let the object move so that its image (fig. 2) in red light shifts its position from $r$ to $r'$; the corresponding image in blue light will shift from $b$ to $b'$, while the center of the diffusion circle on the retina, supposed to be at $r$ for convenience, shifts from $r$ to $b'_1$. It is at once obvious that $rr'/bb' = n_2r/n_2b$; also $bb'/rb_1' = \pi_2b/\pi_2r$; whence $rr'/rb_1' = n_2r \,.\, \pi_2b/n_2b \,.\, \pi_2r$. From the table of dimensions given above this ratio is found to equal 1·0072; that is to say, when an object having red points is shifted in the visual field, the red points seem to have an angular velocity and an angular acceleration about three-fourths of one per cent greater than that of accompanying blue points. Thus, when the red surface described in the experiment is suddenly set in motion, the eye, for an instant fixed, judges of its acceleration and of the less acceleration of the green; then, following it in its motion until it is arrested, concludes that the more refrangible color is left behind—a false judgment which is corrected by the sense of a gradual approach of the green to its true position of rest, just as when the eyes, observing a procession of points passing fixed points, corrects a false judgment as to the place of the former, when the motion suddenly ceases, by an apparent temporary motion in the opposite direction. Of course, if we gain our notion of the angular velocity of the green areas from sharp visual perceptions of their boundaries, the illusion ought not to appear; it is only when the position of the colored area is recognized by its color alone that the effect becomes striking; hence the significance of faint illumination.

### IV. *Binocular Color Relief.*

This is an optical illusion not noted in Helmholtz but described and studied at length by W. Einthoven, who was incited to the investigation by Donders.* According to this writer, Professor Donders was the first one to record the fact that red and blue objects in the same plane appear to most observers, when looked at with both eyes, to lie in different planes, especially when on a black background. To him, as well as to Einthoven, the red appears nearer than the blue. The explanation offered by Einthoven can be described by reference to fig. 1 above. Imagine both axes of the vision converged towards a red point which is accompanied by a blue point just above it: the red images would fall on the points of distinct vision, while the centers of the diffusion circles for blue would fall on disparate points of the retinas nearer the median plane, just where sharp images of a more distant red point would fall; hence the interpretation of the resulting sensation is that the blue point is in fact more remote. He finds evidence in favor of this view by the ingenious experiment of cutting off, by means of movable diaphragms in front of the eyes, first the inner halves of the pupils and then the outer; by this means he enhances or inverts the illusion. His experiments are easily repeated and are highly interesting.†

There are, however, serious objections to this explanation, not only as accounting for the observations, but also from theoretical considerations. Of about thirty individuals investigated Einthoven found that nearly one-third were not confident at first that there was any sensation of relief, while ultimately about half recognized the relief as did Donders, and the other half inferred an inverted order. This general conclusion is fairly well supported by my own more limited experiments. According to the theory, we are obliged to conclude that half of those investigated had the centers of their pupils lying on the nasal side of the axes of vision, and half on the temporal. It is, however, quite certain that a displacement of the pupil towards the nasal side of the axis of vision is extremely rare; consequently there seems to be no escaping the conclusion that similar visual impressions receive, not merely unlike, but opposite interpretations in different individuals. Any acceptable theory must adapt itself to this fundamental fact.

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* Stereoskopie durch Farbendifferenz. Graefe's Arch., xxxi (3).

† A convenient and interesting modification of this experiment may be made by observing a flat surface divided into separated areas of saturated colors through a binocular telescope of which the separation of the axes can be varied at will. The familiar prismatic binoculars are best adapted to the purpose, and any mosaic glass window in which the colors are vivid forms a far better object than colored pigments. If the axial separation is a little greater than that of the eyes, a striking relief will be observed in the sense described above, while a smaller separation will invert the relief.

It seems to me that we can find a probable explanation in the following considerations. Imagine a number of red points distributed in two parallel planes which lie at right angles to their direction from the observer. If the eyes be fixed upon one of the points in the nearer plane, the images of all the other points in that plane will fall on pairs of congruent points of the two retinas, but the images of the points on the more remote plane, which will be quite sharp if the separation of the planes is moderate, will fall on disparate points of the two retinas. Now consider the case of red and blue points in a single plane. Here, if the eyes be fixed upon one of the red points, all the other red points will have their images on congruent points of the right and of the left retina, while the blue points, relatively very diffuse as compared to the images of the more distant red points in the former case, will fall on disparate points. So far there is a formal similarity between the two cases, but it cannot be carried further: in the first case a simple change of convergence of the axes of vision will change the disparate points to congruent, and *vice versa*, while in the second case no such change can produce such an effect; but a change of accommodation proper to blue light will do so at once. The resemblances and differences are such, therefore, that it should hardly surprise us that certain persons recognize the second case as only a confusion of visual images, when others interpret the effect as a sort of chromatic relief; nor is it astonishing that of the latter group, since there is really no fundamental relation between the two phenomena, some should imagine the red to be nearer than the blue points and others invert the order. It is singular, however, that Einthoven found those whom he observed to be distributed so nearly equally among the three classes.

The experiments of restricting the pupils by screens in front of the eyes is by no means conclusive; indeed, it is questionable whether it has any bearing whatever upon the phenomenon. The screens will, primarily, increase very greatly the separation of the centers of the red and blue areas on the retinas which represent the images of the points; moreover, the areas themselves will be much decreased. This will become evident from an inspection of fig. 1. But, as is easy to prove by a diagram, any lateral change of the common point of fixation will produce a relative change in the position of the colored areas on the retinas, which can be compensated by an alteration in the convergences of the axes, and thus the phenomenon is reduced to one which admits of a simple stereoscopic interpretation in complete accordance with the observations. This is because such a shifting—whether produced by a change in the direction of vision or by a change of place in the object itself—partially uncovers one pupil while increasing the obstructed portion of the other, in short, virtually moves one pupil inwards and the other outwards. The resultant effect is like that produced by placing a thin wedge of glass before one eye, when the red appears in advance of the blue if the thicker edge of the wedge is on the nasal side; a reversal of the wedge inverts the apparent relief.

There is, however, one phenomenon which often gives a determining impulse to the interpretation in accordance with the experience of Donders, namely, the relative angular displacement of different colors upon the retina. Thus, in my own case, although quite unable to recognize anything like stereoscopic relief among a series of strongly colored figures on a black background when the eyes are fixed pretty steadily upon them, the relief appears very striking when I walk past it, or when the object as a whole is moved to and fro. So too, in the experiment of the fluttering hearts described above, although there is no chromatic relief under ordinary illuminations, such relief is an invariable accompaniment of the fluttering when produced. As has been shown above, the angular accelerations and angular velocities of moving objects in the visual field would vary with their color, so that colors of greater refrangibility would appear to change their directions from the observer more slowly, exactly imitating in this particular the effect of greater distance.

The illusion described would appear of rather abstract scientific interest were I not convinced that the incomparable French artists of the thirteenth century had recognized it and employed it for the purpose of artistic expression. Indeed, it was a casual inspection of the marvelous medieval windows in the great cathedral at Bourges which first turned my attention to the studies embodied in these papers, and which persuaded me that the one essential distinction between these antique windows and their unsatisfactory modern imitations lies in the knowledge, possessed by the old artists, of the effect gained by an ordering of their vivid colors so that the resulting chromatic binocular relief should fit the composition of their pictures. As far as known to me, the most beautiful surviving examples of this lovely art, as well as the most convincing support for the views here presented, are contained in that unapproached collection; and not alone in the wonderful achievements of those forgotten artists, but also in the instructive failure which has attended modern restorations.*

This is not the place to suggest reasons why so charming an art should hardly have survived the thirteenth century, nor to discuss certain peculiar restrictions to which the artists subjected themselves; but were such an extention of this paper desirable, it seems to me that it would add material weight to the explanation, founded upon principles of physiological optics, of the acknowledged superiority of antique mosaic windows over their modern imitations.

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*In two quadrifoils in the window given by the Guild of Tanners the artist has chosen a red background in place of the almost universal blue; but he has reversed the order of his colors throughout the composition so that the effect, to my eyes at least, was that of two charming little intaglios. It was this which first suggested to me the distinction between ancient and modern mosaic windows described above and which I thought abundantly verified by subsequent observations. Certain very puzzling contradictions to this theory—I have no means now of determining how many—were eliminated by a subsequent discovery that considerable areas of some of the windows are nineteenth century substitutions for the original designs which had been lost. There was no suggestion of this significant fact in my hands at the time of my visit.

Yale University, May, 1905.

## Art. XLIII.—*On the Natural Iron-Nickel Alloy, Awaruite;*
### by George S. Jamieson.

Two terrestrial iron-nickel alloys from adjoining localities will be described in this paper. One from Josephine Co., Oregon, which has already been investigated by Mr. W. H. Melville,* came through Mr. Maynard Bixby of Salt Lake City, Utah. The other, found at South Fork, Smith River, Del Norte Co., California, was from Dr. David T. Day, Chief of the Division of Mining and Mineral Resources of the United States Geological Survey. Both specimens had been sent to Professor S. L. Penfield, at whose advice this investigation was undertaken.

The specimens from Josephine County were water-worn, bean-shaped pebbles, varying in size from a few millimeters to two centimeters in diameter and were composed not only of the alloy, but also of more or less siliceous matter. Thin sections showed that the alloy was of a spongy nature, binding together and enclosing particles of silicate, which had the appearance of serpentine and gave the chemical reactions for that substance. In a steel mortar, the pebbles were easily broken into a powder and no mechanical method of making a separation of the metal from the serpentine seemed possible. A chemical separation, however, was easily effected by treating the powder with water and iodine at ordinary temperature. A complete solution of the alloy was thus obtained in about a day, while the siliceous matter was not dissolved by this treatment. The insoluble silicate was filtered on asbestos, air dried, and weighed. Duplicate analyses were made with the following results:

| | | |
|---|---|---|
| Insoluble silicate | 24·15 | 24·55 |
| Iron | 19·17 | 18·95 |
| Nickel | 56·30 | 56·07 |
| Cobalt | ·35 | ·35 |
| Phosphorus | ·04 | ·04 |
| Sulphur | ·09 | ·09 |
| | 100·10 | 100·05 |

Deducting the insoluble silicate and recalculating the remaining constituents to one hundred parts, the following percentages were obtained:

| | | |
|---|---|---|
| Iron | 25·24 | 25·11 |
| Nickel | 74·17 | 74·30 |
| Cobalt | ·46 | ·46 |
| Phosphorus | ·04 | ·04 |
| Sulphur | ·09 | ·09 |
| | 100·00 | 100·00 |

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* This Journal [3], xliii, 509.

These results differ but slightly from those obtained by Melville, who found iron 23·22, nickel 60·45, and 15·83 per cent of other constituents. The metals calculated to 100 per cent equal, iron 27·75, and nickel 72·25.

The sample of iron-nickel alloy which came from Smith River, California, was in the form of grains of remarkably uniform size, about 0·15 millimeters in diameter, with an occasional larger grain, up to 1·5 millimeters. The metallic sand, for that is what it appears to be, was obtained from gold washings and was chiefly composed of the alloy, but mixed with magnetite, and a very little chromite. As no mechanical method for separating the alloy from the magnetite seemed to give satisfaction, a separation by chemical means was again resorted to. The size of the grains, which could not be reduced to powder, made the solution in iodine altogether too slow for practical purposes. The alloy was found, however, to be easily soluble in warm dilute nitric acid (one part conc. $HNO_3$: two parts $H_2O$), while the magnetite was not appreciably attacked, if at all. Duplicate analyses were made with the following results:

| | | |
|---|---|---|
| Insoluble matter | 9·45 | 9·97 |
| Iron | 19·21 | 18·97 |
| Nickel | 68·61 | 68·46 |
| Cobalt | 1·07 | 1·07 |
| Copper | ·59 | ·56 |
| Sulphur | ·05 | ·05 |
| Phosphorus | ·04 | ·04 |
| Silica | ·10 | ·19 |
| Magnesium oxide | ·50 | ·44 |
| | 99·62 | 99·75 |

The specific gravity was found to be 7·45 or, allowing for 9·7 per cent of magnetite, the value 7·85 is obtained for the alloy.

Deducting the insoluble matter, consisting of the magnetite, a small amount of chromite and the traces of silica and magnesium oxide, and recalculating the remaining constituents for one hundred parts, the following percentages were obtained:

| | | |
|---|---|---|
| Iron | 21·45 | 21·28 |
| Nickel | 76·60 | 76·79 |
| Cobalt | 1·19 | 1·20 |
| Copper | ·66 | ·63 |
| Phosphorus | ·04 | ·04 |
| Sulphur | ·06 | ·06 |
| | 100·00 | 100·00 |

In dissolving the alloys in hydrochloric acid, it was noted that there was no odor of hydrocarbons, such as is observed when iron and steel are dissolved, nor was there any evidence of graphitic carbon.

These two iron-nickel alloys are quite similar in composition to those which have already been described from other localities, and for comparison, a table has been arranged to show percentages of iron and nickel which these various alloys contain. The first analysis is that of an alloy found at Gorge River, which flows into Awarua Bay on the west coast of South Island, New Zealand, described by W. Skey[*] in 1885 and to which the name awaruite was given. The second analysis, by A. Sella,[†] is of an alloy from the gold-bearing sand of the Elvo River, near Biella, Piedmont, Italy. The third analysis, by Melville, is of material from Josephine Co., for which the name Josephinite was suggested. No. 4 is a recent analysis by F. G. Wait, quoted by G. C. Hoffmann,[‡] of a similar alloy from Fraser River, British Columbia, to which Hoffmann has given the name souesite, as stated by him, "to distinguish this find from that of other naturally occurring iron-nickel alloys." The last two analyses are those of the present writer.

| | Locality. | Analyst. | Fe. | Ni. | Co. | Cu. | Other constituents. |
|---|---|---|---|---|---|---|---|
| 1. | New Zealand | Skey | 31·02 | 67·63 | ·70 | none | ·63 |
| 2. | Piedmont, Italy | Mattirolo | 26·60 | 75·20[§] | .. | none | .. |
| 3. | Josephine Co. | Melville | 27·41 | 71·35 | ·65 | ·59 | .. |
| 4. | British Columbia | Waite | 22·30 | 76·48 | none | 1·22 | .. |
| 5. | Josephine Co. | Jamieson | 25·24 | 77·17 | ·46 | .. | ·13 |
| 6. | Del Norte Co. | " | 21·45 | 76·60 | 1·19 | ·59 | ·10 |

It is seen from a glance at the analyses of the alloys from the five different localities, that there is a certain uniformity in composition, but that they are not a definite compound of iron and nickel is evident, nor would this be expected; with Fe : Ni = 1 : 3, the percentages are Fe 24·00 and Ni 76·00, to which most of the analyses approximate, while for the ratio 1 : 2 the values are Fe 32·19 and Ni 67·81. It seems unfortunate that so rare a substance should have received three distinct names, awaruite, josephinite, and souesite, and it is urged that awaruite, which has priority, should alone be used.

As regards the occurrence of the alloy, its association at Josephine Co., Oregon, with serpentine, and at New Zealand, Piedmont, Frazer River, and Del Norte Co., Cal., with chromite, suggests that it is a material which has separated from basic peridotite rocks, and, as it seems to have no tendency to deteriorate by oxidation, it is found as a heavy constituent in adjacent river sands.

In closing, it is desired to thank Mr. Bixby and Dr. Day for the material which they had sent to the laboratory for investigation, and also Professor S. L. Penfield for his help and valuable suggestions.

Sheffield Scientific School of Yale University, May, 1905.

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[*] Trans. N. Zeal. Inst., xviii, 401.

[†] Comp. Rend., cxii, 171.

[‡] This Journal (4), xix, 319, 1905.

[§] Contains cobalt.

## ART. XLIV.—*Hyopsodidæ of the Wasatch and Wind River Basins;* by F. B. LOOMIS.

DURING the early summer of 1904, Amherst College sent a party into the Wasatch along the Big Horn River, where an unusually complete collection was obtained: later, collecting was continued in the Wind River beds, a new and rich locality having been found on the east side of Bridger Creek, about ten miles northwest of Lost Cabin Post Office, Wyoming. In the latter basin, the fauna of which has been but meagerly known, some 400 specimens, distributed among about 50 species, were found. As a large number of the species are new, the material, together with that of the Wasatch, has been used in a study of the families represented; reference also having been made to other collections from these horizons, especially those of Cope and the American Museum of Natural History, both being in that museum.

### Order INSECTIVORA.

### Family *Hyopsodidæ*, Schlosser.

This family as now known includes two genera, *Hyopsodus* and *Sarcolemur*, both from the North American Eocene. The genera were originally classed among the Primates; and so in Cope's* and Osborn's† papers are placed under the suborder Mesodonta; or by Schlosser‡ under the equivalent Pseudolemuroidea. Wortman,§ however, has classed them among the Insectivora, giving the following reasons: 1, the incisors are 3/3; 2, the tympanic bulla is not ossified; 3, the structure of the molars is not Primate; 4, the enterocarotid circulation is that typical of the Insectivora: 5, the limb bones differ from those of any known Primate; 6, the metapodials are not Primate; 7, the phalanges are short; 8, the hallux is not opposable. The writer too would place the Hyopsodidæ among the Insectivora and in the neighborhood of the genus *Erinaceus*.

The family may be defined as follows: teeth in a continuous series, cusps more or less pointed; superior molars with intermediate cusps (protoconule and metaconule); posterior internal cusp (hypocone) less developed than the other cusps; the lower molars with a low anterior buttress (protolophid) connecting the two anterior cusps; a second buttress behind the first, connecting the same cusps posteriorly (metalophid) more or less developed; the entoconid feebly developed (see fig. 1).

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* Rep. U. S. Geol. Surv., iii, 738, 1884.

† Bull. Amer. Museum Nat. Hist., 178, 1902.

‡ Die Affen, Lemuren, Chiropteren N. S. W., 21, 1890.

§ This Journal, xv, 400, 1903.

Two genera are distinguished by Cope and Osborn on the condition of the metaconid: when simple, *Hyopsodus:* if bifid, *Sarcolemur.* The two genera are certainly distinct but further characters are required to separate them; for several jaws, which, in all other features, are most closely related to *Hyopsodus*, still have the metaconid bifid. This character has also been noticed as occurring in the genus *Eohippus*, *Phenacodus*, and *Systemodon*, and is not, therefore, considered alone enough to separate the two genera. The bifid metaconid is used below to distinguish some of the species of *Hyopsodus.*

*Hyopsodus* is characterized by lower wider teeth, the cusps being blunter; the fourth premolar is wide and not compressed, having fewer and less developed cusps. It occurs in the Wasatch, Wind River and Bridger horizons. In several species there is a tendency to have the metaconid bifid, but it is never as marked as is characteristic of *Sarcolemur.*

*Sarcolemur* is characterized by narrow trenchant teeth, with pointed cusps; the fourth premolar is much compressed and has the anterior cusps well developed. It is as yet known only from the Bridger, and of the promolars only the fourth is known.

### Hyopsodus Leidy

*Lemuravus* Marsh, *Stenacodon* Marsh, *Microsus* Leidy, *Diacodexis*, Cope.

The genus was founded by Leidy* on an imperfect lower jaw of *H. paulus* from the neighborhood of Ft. Bridger. The name Microsus† was given the same year to a second species differing only in the proportionate depth of the mandibular ramus. Stenacodon‡ was founded by Marsh on what proves to be a last lower molar, the genus being separated on the ground that there was no cingulum. Lemuravus§ was proposed for a species on the basis of the incisor formula being 3/3 which, later, proved to be true for *Hyopsodus. Diacodexis*‖ was proposed by Cope for a specimen, including premolars of *Eohippus.* As yet the only members of the family found in the Wasatch and Wind River horizons belong to the genus *Hyopsodus*, the skeletal features of which are as follows:

The skull is elongate with a level top terminating abruptly behind, the rear of the cranium overhanging the occipital condyles, somewhat as in Rodent skulls. The zygomatic arches are slender but widely arched. On the deep lower jaw, the anterior border of the surface for attachment of the masseter muscle lies just under the last molar. The teeth are in a continuous series but without crowding. In the upper jaw, the hypocone of the last molar is merely a rudiment, indicated by a slightly raised portion of the cingulum. Molars one and three have a small but distinct hypocone, the cingulum running to it. The first and second premolars have a single cusp while the third and fourth each have inner cusps. The canines are moderate and the three incisors simple. Specific characters are found only in the cingulum and size of the form. The lower teeth are more varied, especially the last molar. The general topography of a lower tooth with the nomenclature here used is given in fig. 1. On the front part of the tooth the protoconid and metaconid are the principle cusps, connected anteriorally by a low curved protolophid. The inner end of this is in some species developed into a tiny cusp, the possible equivalent of the paraconid. Behind, these same two cusps are usually united by a metalophid, and the hypoconid is connected to the metaconid by a more or less developed ridge (hypolophid). The entoconid is always feebly developed, and between it and the hypoconid there is a strong hypoconulid. The fourth premolar has the protoconid and deuteroconid well developed, and from the former a ridge runs to the front, while a second ridge runs from the same cusp to the rear, developing in some species one or two cusps on the margin. The third premolar is similar but simpler.

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* Proc. Acad. Nat. Sci., Phila., 110, 1870.
† Same cit., p. 113.
‡ This Journal, ii, 210, 1892.
§ Same cit., vol. iv, p. 239, 1875.
‖ Proc. Amer. Phil. Soc., vol. xxi, 181, 1883.

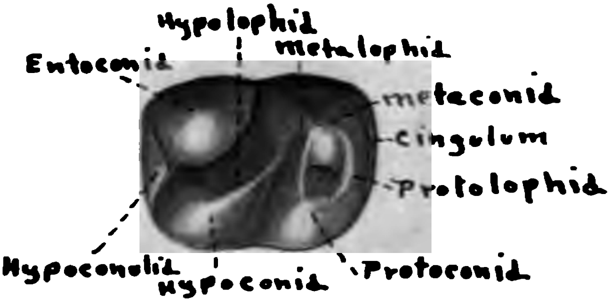

Fig. 1. A typical Hyopsodus lower molar. × nat. size.

Of the milk dentition I have seen nothing which is worthy of note among so many specimens.

The skeletal material, while rather fragmentary, gives many of the characters which determine the ordinal position of genus. The stout humerus is widened at the distal end and pierced by a supratroclear foramen (similar to *Erinaceus*).

The olecranon process of the ulna is long (distinctly an Insectivor character), and the greater sigmoid cavity is very wide, the less sigmoid cavity being also well marked. The femur is short, thick and flattened, and has a strong third trochanter. (This is not found in Primates, but is especially well marked in *Erinaceus.*) Finally, according to Wortman, the metapodials are short and stout, and the hallus not opposable (both Insectivor features).

### *Hyopsodus simplex* sp. nov.

The specimens of this, the smallest and at the same time most abundant of the Wasatch species, were referred by Cope to *H. vicarius* and *H. paulus*, both of the Bridger horizon. Osborn[*] provisionally referred them to *H. miticulus* Cope, from the New Mexico Wasatch, but differing from *H. simplex* in being somewhat larger and having a low ("Esthyonyx-like") heel and in having the posterior cusps more developed.

For a type, a lower jaw of the left side carrying the fourth premolar and the molars is chosen. All the teeth of the lower jaw are short and wide with obtuse cusps. On each there is a trace of a cingulum about the rounded anterior outer corner of the tooth and also externally between the cusps. On the wide fourth premolar the protoconid is better developed than the deuteroconid, and behind there is a wide basin, the posterior margin of which is crenulated. On molars one and two the protolophid is well developed, while there is not more than a trace of a metalophid. A strong ridge runs from the hypoconid to the metaconid. The entoconid is weak and has a small tubercle in front of it, very characteristic of the species. On the last molar the heel region consists of a basin bounded behind by a high crenulated rim, on which the hypoconulid and entoconid appear as crenulations, scarcely larger than the others.

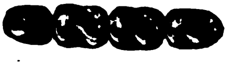

FIG. 2. *Hyopsodus simplex.* Left ramus. × $\frac{3}{1}$.

Each of the upper molars has the cingulum in front, outside and behind. The last of these molars is much reduced and is without a true hypocone. Promolars three and four have each an internal cusp, while the front two are simply cusps.

Affinities—*H. simplex* is about the same size as *H. vicarius* from the Bridger, but the molars are shorter and more robust, while the hypoconulid is less developed and has an extra tubercle in front of it. *H. paulus* is a much larger and better developed species. *H. miticulus* is the nearest form, the more specialized and low talonid, and the superior size distinguishing it from *H. simplex*.

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[*] Bull. Amer. Museum Nat. Hist., xvi, 183, 1902.

Locality—27 specimens were collected from both the upper and lower beds of the Wasatch on Gray Bull River.

They run very uniform in size, the length of the three lower molars being between 10 and 11$^{mm}$. In a few cases the last lower molar was considerable smaller than the normal.

### *Hyopsodus miticulus* Cope.*

This form from the New Mexico Wasatch is thus described by Cope: "Parts of several specimens of this species show that the molars are similar in size to *H. paulus*, but that it has a much smaller last inferior molar, which has such a low heel as to resemble the corresponding tooth of the species of *Esthonyx*."

The species seems to resemble *H. simplex* most, but is larger and differs in the heel being low, and more developed. The last molar is also proportionally smaller. The two cannot in the writer's opinion be included in one species.

### *Hyopsodus lemoinianus* Cope.†

This species presents several difficulties on account of the large amount of variation in size, and in the development of both the metaconid and the metalophid; but in as much as these variations do not seem to be constant, and as intermediate forms are found between the widest variations, all these related forms have been assigned to the one species. *H. lemoinianus* was established by Cope, who figured a left ramus with the molars, on which the metaconid is but slightly bifid. Osborn figures a second specimen with the metaconids also but little twinned. Most of the Amherst specimens have this cusp markedly bifid, as is seen in the specimen figured.

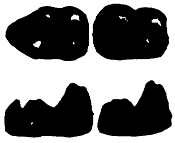

FIG. 8. *Hyopsodus lemoinianus.* × 3.

The species may be described as follows: There is a cingulum on the front of the tooth, and between the external cusps of the moderately stout teeth. On molars one and two, there is developed on the inner end of the protolophid a small but distinct paraconid, which makes the metaconid appear bifid. The metalophid is either entirely wanting or but moderately developed. The entoconid is small, as is also the hypoconulid. The last lower molar is longer, and similar except that the hypoconulid is developed into a prominent heel. On the upper molars the cingulum is well marked and the cusps fairly high.

The three lower molars measure 13 to 15$^{mm}$, there being considerable variation in size. The nine specimens collected all occurred in the basal beds along the Gray Bull River, Wyoming.

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* Rep. Vert. Fossils of New Mexico, Appen. F.F., Rep. Chief. Eng., 8, 1874.
† Proc. Amer. Phil. Soc., xx, 148, 1881.

### *Hyopsodus powellianus* Cope.*

This, the largest species of the *Hyopsodidæ*, occurs but infrequently, being known by parts of the lower jaw only. The teeth are low and wide with stout, low cusps and no cingulum. The metaconid is simple and widely separated from the protoconid. The hypoconulid is small, even on the last molar. The protolophid is low and the metalophid lacking. On the last molar the entoconid region is occupied by two small cusps. The three lower molars measure together 18$^{mm}$. In the Amherst collection the species occurs but twice, both specimens coming from the basal beds of the Wasatch of the Gray Bull River, Wyoming.

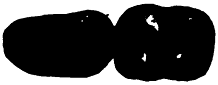

FIG. 4. *Hyopsodus powellianus.* × ⅔.

### *Hyopsodus laticuneus* Cope.†

A single specimen represents this species, on which the genus *Diacodexis* also hangs. The specimen included both upper and lower teeth, but Matthew has removed the lower premolars and assigned them to *Eohippus index*, leaving the upper molars which are characteristic of the genus *Hyopsodus*, and a last lower molar which is distinguished by low broad crown with obtuse cusps, lack of an external cingulum and the entoconid region occupied by two small cusps, and lastly by the metaconid being bifid. This last character alone distinguishes the species from *H. powellianus* to which it is equal in size. The specimen came from the Wasatch in the neighborhood of Gray Bull River.

In the Wind River horizon, four species are known, three of which are here described for the first time. This horizon is marked by a slight advance in the development of the genus. The hypoconulid is stronger, especially on the last molar, and in the entoconid region there is only a single strong cusp, the entoconid. The metalophid is universally present.

In the locality found by the Amherst party the specimens of *Hyopsodus* formed fully a third of the collection.

### *Hyopsodus wortmani* Osborn.‡

The type specimen (including an upper and a lower jaw) was first figured by Cope among *H. vicarius* specimens, and was later by Osborn removed and used as the type of this species, the description however being very meager.

The teeth are moderately wide with rather low cusps and a cingulum along the front only. On the fourth premolar the protoconid and deuteroconid are connected by a sharp ridge; the basin behind is wide, and on the outer side of the rim is a small cusp. The protolophid and metalophid are both well developed on the first and second molars but on molar three the latter is very weak. The hypoconulid is small on the first two molars but developed into a prominent heel on the last, the entoconid being tiny. The upper molars are those typical of the genus, having a cingulum in front, outside and behind.

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* Rep. U. S. Geol. Surv., iii, 235, 1884.

† Proc. Amer. Phil. Soc., xx, 181, 1881.

‡ Bull. Amer. Museum Nat. Hist., xvi, 185, 1902.

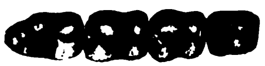


Fig. 5. *Hyopsodus wortmani.* × $\frac{2}{1}$.

The specimens run uniform in size, the three inferior molars measuring $12^{\mathrm{mm}}$. On Bridger Cr., 37 specimens were collected and the species occurs also in the other Wind River localities.

### *Hyopsodus minor* sp. nov.

Though but one example of this tiny form was found, it differs so materially from *H. wortmani* that it is impossible to include it in that species. The type specimen is part of the right ramus with the three molars measuring together $10^{\mathrm{mm}}$.

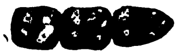


Fig. 6. *Hyopsodus minor.* × $\frac{2}{1}$.

The teeth are short, with obtuse but well-separated cusps, and have a cingulum in front and a trace of it between the external cusps. The proto- and meta-conids are set close together and united by both a protolophid and metalophid. The hypoconid has a strong ridge running to the metaconid, while the hypoconulid and entoconid are both strongly developed.

The species is distinguished by its small size, presence of a cingulum externally and the strength of the ento- and hypoconulid. The locality is Bridger Cr., Wyoming, in the Wind River horizon.

### *Hyopsodus browni* sp. nov.

This, the most abundant species in the Wind River beds, is named in recognition of the successful work of Mr. T. C. Brown in collecting these forms. The type is a left ramus with the molars and fourth premolar; while an upper jaw with premolars three and four is associated with it as co-type. A less complete specimen has both upper and lower dentition.

The teeth of the lower jaw are short and stout with obtuse cusps, and a cingulum along the front only. On the fourth premolar the deuteroconid is merely indicated by a small cusp, and behind on the proterior margin of the basin, there is a small external cusp. On all the molars the proto- and metaconids are set close together and united by both a proto- and meta-lophid. The hypoconid is large and connected the metaconid by a wide ridge. The hypoconulid is rather large on all the molars but does not make a strong heel on the third molar.

The upper molars have a cingulum in front, outside and behind; on the which, where it meets the ridge from the paracone, there is a strong parastyle. The protoconule is closely united to the protocone. The last molar is large, but still lacks the hypocone. The third and fourth premolars have the parastyle but lack the intermediates and hypocone.

The species includes the medium sized individuals of the Wind River, the three lower molars measuring 15$^{mm}$. It compares in size to *H. lemoinianus* but lacks the external cingulum, and has a simple metaconid as well as having much more obtuse cusps. There are 45 specimens in the Amherst collection all from Bridger Cr., Wyoming.

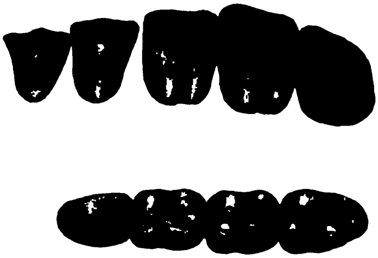


FIG. 7. *Hyopsodus browni.* × $\frac{3}{1}$.

*Hyopsodus jacksoni* sp. nov.

In many ways this is the most specialized of the *Hyopsodidæ*, and it has been named in recognition of the interest and coöperation of Mr. E. E. Jackson in the Amherst expeditions. The type is a right ramus with the molars and the fourth premolar, and a third premolar from the left side. The co-type contains three upper molars.

The lower molars are rather narrow with moderately high cusps and a cingulum along the front side only. The metaconid is bifid, strongly so on the first molar, and just visibly so on the last. The protoconid and metaconid are widely separated and connected by the protolophid only. The hypoconulid is throughout small; and on the third molar connected by a ridge to the entoconid. The fourth premolar is complex, the protoconid and deuteroconid being connected by a ridge; and there are two well-developed cusps behind on the posterior rim. The third premolar is similar but lacks the two posterior cusps. The upper molars are those typical of the genus, with the cingulum well developed on the outside. A distinct parastyle is formed on the anterior external angle of the cingulum. The posterior intermediate is isolated while the anterior one is connected to the protocone.

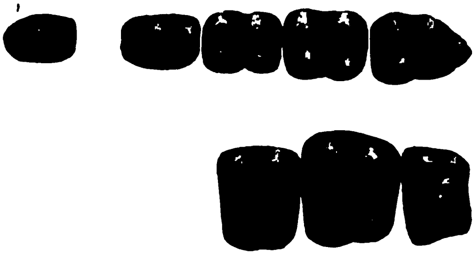


FIG. 8. *Hyopsodus lawsoni.* × $\frac{3}{1}$.

The three lower molars measure together 16$^{mm}$. 26 specimens were found along Bridger Cr., Wyoming.

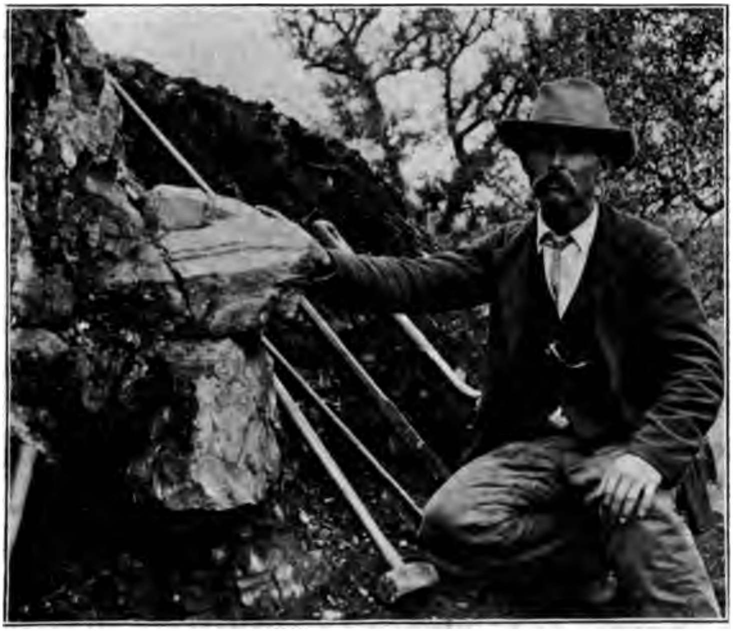
## HYOPSODUS.

| | H. simplex. | H. miticulus. | H. lemoinianus. | H. powellianus. | H. laticuneus. | H. wortmani. | H. minor. | H. browni. | H. lawsoni. |
|---|---|---|---|---|---|---|---|---|---|
| Lower Premolar 4 | Deuteroconid strong:<br>posterior margin of basin crenulated without cusps | | Deuteroconid strong and bifid:<br>posterior margin of basin with two tiny cusps | | | Deuteroconid smaller than protoconid:<br>connected by ridge:<br>posterior margin with external cusp | | Deuteroconid very small:<br>posterior margin with external cusps | Deuteroconid connected to protoconid by ridge:<br>posterior margin with two cusps |
| Lower molars 1 & 2 | External cingulum, traces:<br>hypoconulid large:<br>no metalophid:<br>entoconid with tubercle in front:<br>metaconid simple | No external cingulum:<br>hypoconulid medium:<br>no metalophid:<br>entoconid simple:<br>metaconid simple | External cingulum, traces:<br>hypoconulid strong:<br>no metalophid:<br>entoconid medium simple:<br>metaconid bifid | No external cingulum:<br>hypoconulid small:<br>no metalophid:<br>entoconid small:<br>metaconid simple | | No external cingulum:<br>hypoconulid small:<br>metalophid:<br>entoconid small:<br>cusps alternating:<br>metaconid simple | No external cingulum:<br>hypoconulid large:<br>metalophid:<br>entoconid medium:<br>metaconid simple | No external cingulum:<br>hypoconulid large:<br>metalophid:<br>entoconid medium:<br>cusps alternating:<br>metaconid simple | No external cingulum:<br>hypoconulid small:<br>metalophid weak:<br>entoconid small:<br>metaconid bifid |
| Lower molar 3 | External cingulum, traces:<br>metaconid simple:<br>entoconid one of several small tubercles:<br>heel not prominent | No external cingulum:<br>metaconid simple:<br>entoconid with a small tubercle in front of it;<br>heel fairly prominent | External singulum, traces:<br>metaconid bifid:<br>entoconid with small tubercle in front:<br>heel prominent | No external cingulum:<br>metaconid simple:<br>entoconid with large tubercle in front of it:<br>heel not prominent | No external cingulum:<br>metaconid bifid:<br>entoconid with small tubercle in front of it:<br>heel fairly prominent | No external cingulum:<br>metaconid simple:<br>entoconid with small tubercle in front of it:<br>heel prominent | No external cingulum:<br>metaconid simple:<br>entoconid simple:<br>heel prominent | No external cingulum:<br>metaconid simple:<br>entoconid simple:<br>heel medium | No external cingulum:<br>metaconid slightly bifid:<br>entoconid simple:<br>heel prominent |
| Length of 3 lower molars | 10–11 mm | 12 mm | 13–15 mm | 18 mm | About 18 mm | 12 mm | 10 mm | 15 mm | 16 mm |
| Horizon | Wasatch | Wasatch (New Mexico) | Wasatch | Wasatch | Wasatch | Wind River | Wind River | Wind River | Wind River |
| No. of | 27 | 0 | 9 | 2 | 0 | 37 | 1 | 45 | 26 |

## ART. XLV.—*Some Results of late Mineral Research in Llano County, Texas;* by WILLIAM E. HIDDEN.

THE noted gadolinite locality in Llano County, Texas, known as Barringer-Hill, was reopened* and thoroughly prospected by the writer, during the winter of 1902–03, with very encouraging results. All the old cuts were cleaned out and extended, and a systematic development of the mine was begun at the southeast point of the hill, and at as low a level as the river terrace would permit. The plan was to remove the hill by blasting and gradually make a dump of it towards the near-by Colorado river. The season proved to be a very propitious one and much good work was accomplished. Seven years had elapsed since any work had been done upon the property, but in a short time all the old familiar minerals had been rediscovered either in new openings or in extensions of the original workings of Mr. Barringer.

1



73-lb. mass of Gadolinite in place.

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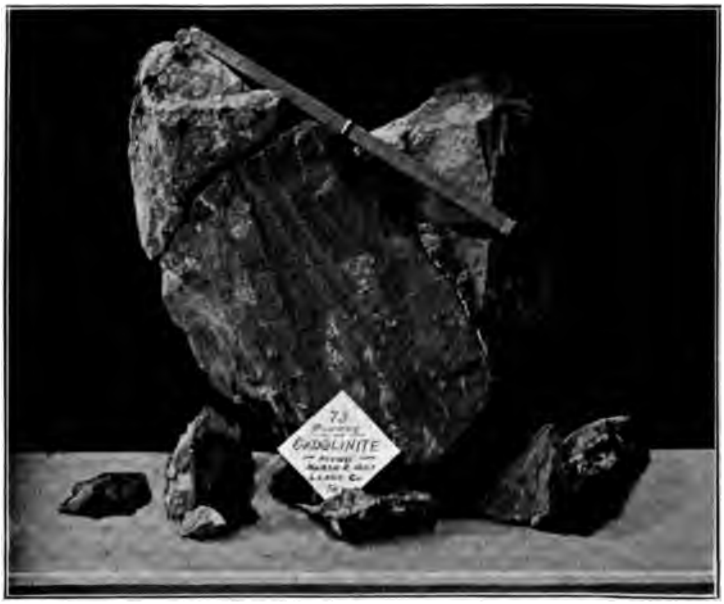
* The development was undertaken under the auspices of the Nernst Lamp Company, of Pittsburgh, Pa., to whom all the output was sent.

Among the most notable discoveries of "Barringer-Hill" minerals, at this time, were the double crystal of gadolinite that weighed seventy-three pounds and an eighteen-pound mass of yttrialite (see figures 1, 2 and 3); a mass of pure allanite that weighed over three hundred pounds; about fifty pounds of thoro-gummite, among which were pieces weighing fully a pound and some few good crystals. Of fergusonite several very pure masses and large aggregations of rough crystals were found, up to five pounds in weight. Of rowlandite one very pure mass weighing just one kilo was obtained; of nivenite and mackintoshite very little was discovered. The mineral

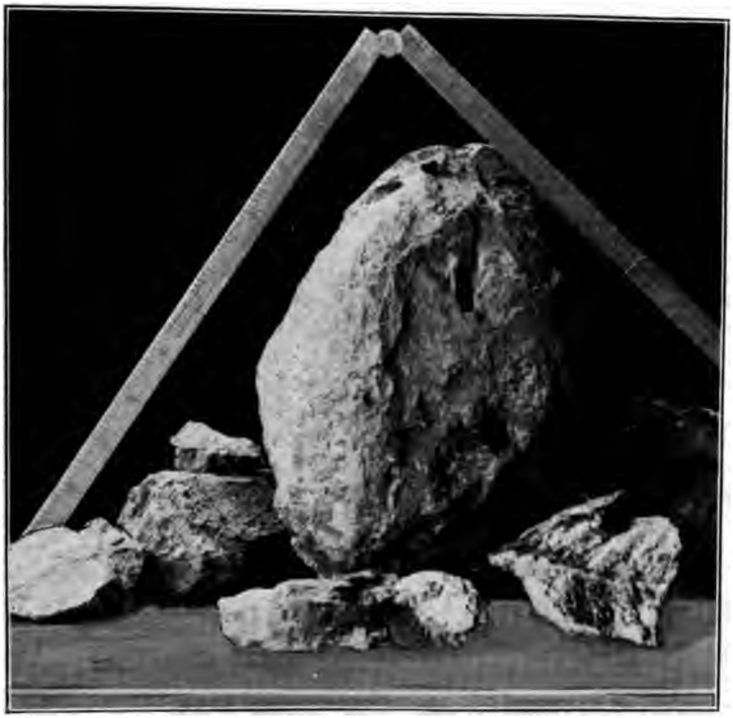
2



species rich in yttrium-erbium were more particularly sought after because thorium and uranium were not used in the "glower" of the Nernst Lamp.

Masses of coarsely crystallized fluorite up to four hundred pounds weight were not rare, and some of these had very large faces of the cube and rhombic dodecahedron. Its color varied from dark green to puce and purple, and colorless transparent rough crystals having remarkably perfect cleavage were sometimes observed. Some of the fluorite was true chlorophane and exhibited a brilliant green light when strongly heated and viewed in the dark. One mass was self-luminous, at night, without heating it. Enormous crystals of orthoclase were common, some over five feet in diameter. Quite frequently small veins of very perfect red feldspar crystals (highly-twinned), and upon which albite crystals were attached, were found bordering the fluorite and penetrating it. In the feldspar, well crystallized menaccanite was sometimes observed, and this mineral is new to the locality. Yellow rutile, of the sagenitic variety, was observed in only one instance and then upon smoky quartz crystals. Polycrase, or an allied species, was seen implanted upon the gadolinite, this is also new to the region. A cavity into which a horse could have been put was discovered on the river side of the mine, and from it a large crystal of smoky quartz was taken that weighed over six hundred pounds. It was forty-three inches high and twenty-eight inches broad and fifteen inches thick. This is now in the University of Texas collection at Austin, Texas.

3



18-lb. mass of Yttrialite.

Very fair amethysts were found in the west end of the hill, in cavities in the feldspar. Masses of biotite, four feet across, were met with and always indicated the presence near-by of the rare-earth minerals. Some of the fluorite contained small thin veins of a very dark mineral, which was deep indigo-purple by transmitted light, and this may, perhaps, betoken the occurrence of a basic fluoride of the yttrium or cerium earths at this mine and in the region generally.

In a period of four months there was taken out of the hill enough of the yttrium ores to suffice for the Company's needs for the balance of the year, and the mine was therefore closed for the season.

In the following winter (1903–4) the work was again resumed at Barringer-Hill, and about a dozen workmen were kept constantly employed for a period of six months. The scheme of development laid down by the writer in 1902, was carried forward with much energy. Considerable "dead-work" was done in the line of removing "topping" and bringing up the "fall" from the river-side of the hill. New cuts were opened, and the whole top of the hill was blasted away. All the work done at the mine thus far has been of the character of open quarry work, with hand-drilling and the use of powder and dynamite. The mine has been proved to have a deep-seated origin and is only one of a series of so-called "blow-outs" in a region that is entirely granitic. Deep work at this locality may be expected to bring to light new combinations of the rare earths and of uranium and of thorium, as well as great quantities of the species for which the hill is already famous. All the old species will probably be found in a purer state and perhaps in their normal condition as when first crystallized. This last mentioned condition is what we are eagerly seeking for in order to clear up the formulae of many of the species.

During last winter's work all the old minerals, excepting rowlandite, were again found and more than one thousand pounds of very pure gadolinite. The seventy-three pound group of crystals (of gadolinite), found in March, 1903, was the greatest "find" of record in this mineral; but just one year later, a mass of roughly crystallized gadolinite was found, partly imbedded in the bed-rock at the northeast corner of the hill, that measured thirty-six inches long, eleven inches thick at the widest part, and weighed a little over two hundred pounds. It was apparently free from alteration, had specific gravity of 4·28 (taken on a very pure fragment), had a bright green chatoyancy at certain angles, and was like glass in its broad obsidian-like conchoidal fracture.

Upwards of a pound of very pure nivenite and not exceeding an ounce of mackintoshite, were picked out of the many boxes of mixed cyrtolite, fergusonite and thoro-gummite.

Only the density of nivenite saved it from being thrown away as magnetite (very abundant at this mine), and but for its associations it would be always neglected except by the expert mineralogist. Equally so with the mackintoshite, its resemblance to the dark cyrtolite and intimate association with it, prevents it from being recognized by the miner or layman. Some day this mine promises to be worked for the two last-named minerals alone and as the main object of mining there, and in the deeper working they should be found abundantly and in a higher state of purity.

*Tengerite (?)*—About ten grams of a white mineral, occurring in semi-globular and flat radiated concretions in the cracks and fissures of the gadolinite, were finally obtained after much labor and search. This quantity was the result of detaching the mineral, bit by bit, from over 300 kilos. of fresh gadolinite. Since the composition of tengerite (to which species this substance is tentatively referred) is unknown, I submitted the rare mineral to Dr. W. F. Hillebrand of the U. S. Geol. Survey for analysis; his report is given in full below. The surprising feature is the presence of glucina (BeO) in the form of carbonate, which is new to science, and this may perhaps indicate a new glucinum mineral mechanically mixed with a basic hydrous carbonate of the rare earths of the yttrium group.

### *Dr. Hillebrand's Report and Analysis.*

"The purest material that could be picked out, from that at my disposal, showed some brown admixture with the white. The following results were obtained from ·3640 gram of this selected material, after deducting ·0262 gram of residue, left after long treatment of the ignited powder with cold and quite dilute nitric acid.

| | | | | |
|---|---|---|---|---|
| $Y_2O_3$ group | 40·8 | per cent | Mol. wt. | 226 |
| $Ce_2O_3$ group | 7·0 | " | " " | 335 |
| $Fe_2O_3$ | 4·0 | " | | |
| BeO (GlO) | 9·7 | " | | |
| $CO_2$ | 19·6 | " | | |
| $H_2O$ above 105° | 14·1 | " | | |
| $H_2O$ below 105° | 3·2 | " | | |
| $SiO_2$ | ·4 | " | | |
| MgO, Alk., loss | 1·2 | " | | |
| | 100·0 | " | | |

All determinations were made on the one portion, the $CO_2$ and $H_2O$ being directly and simultaneously ascertained by ignition in a tube and collection of the escaping gases. The loss in weight of the ignited powder agreed with the sum of the $CO_2$ and $H_2O$ found. Approximate molecular weight determinations of the earths, separated into two portions by potassium sulphate, gave 335 for the cerium group and 226 for the yttrium group, the last being the molecular weight of yttria itself. It is certain that some, if not all, of the ferric oxide reported is foreign to the carbonate, but how much it is impossible to say. The calculated ratios lead to nothing definite, except that the white mineral appears to be a hydrous basic carbonate, but whether a double carbonate of the rare earth metals and glucina, or a mixture, there are no present means of deciding."

*Radio-activity.*—All the minerals of Barringer-Hill have been experimented with to ascertain the extent of this form of energy present. As early as September, 1902, the writer was at work upon it and had then made successful radiographs from specimens mined at this locality as far back as 1889. In the order of their activity, as shown by their own radiographs, I here mention the species in which the phenomena were observed.

*Nivenite* (which is a very soluble variety of uraninite) exhibited the most pronounced radio-activity, and beautiful radiographs were made by placing the mineral outside of a photograph plate-holder. Better ones were procured by placing the mineral in direct contact with the sensitive plate—"Cramer's X-ray." Twelve hours exposure, in the dark, developed very good interference figures; but with forty-eight hours, and up to five days exposure, the outlines became as sharp almost as are shown in photographs by sunlight.

*Mackintoshite* (which is the parent mineral of thoro-gummite) was next in the amount of radio-activity exhibited. It showed about half the intensity of nivenite when compared with equal exposures of the two minerals, side by side, on the same plate.

Positive evidence of the occurrence, within mackintoshite, of little crystals having even a *higher radio-activity* than that shown by the nivenite, was proven by developing the plates used with direct contact. Little bright spots appeared in the field where the less energetic mackintoshite had touched it, and a dull gray border (made by the thoro-gummite coating) united to make a radiograph having *three* degrees of intensity from one mineral specimen. With a strong lens these bright spots, possibly due to a new species, could be identified upon the flattened surface and they were noticed to be very unlike the surrounding mackintoshite. They resembled galena in color and in metallic luster and were quite evenly distributed over the several flat sections examined. Mackintoshite has given evidence, in thin sections, of being translucent, and of a very dull green color by transmitted light, but as the purest material yet analyzed showed (vide Hillebrand's analysis) 4·31 $H_2O$ present, it is possible that these little bright spots are only the normally pure anhydrous mineral. It is tenable also that these little inclusions, with their high radio-activity, are but a normally pure form of nivenite in which only $UO_2$ is present. Since mackintoshite can be rationally interpreted as being a mixture of three parts of thorite with one of uraninite (nivenite), the assumption that a new mineral has been discovered may not stand. The question is certainly one of unusual interest at this time and merits further investigation.

*Thoro-gummite.*—Contact radiographs of this mineral, made from a flattened surface after forty-eight hours exposure, *in the dark*, had much the appearance of ordinary sunlight photographs. All the minute details of structure and varying degrees of radio-activity were beautifully portrayed. It was surprising to note how perfect a picture this mineral could make of itself without any outside aid other than a photographic plate and a long exposure in the dark.

Masses up to a pound weight were found, and this proves that mackintoshite will not be as rare as it is now, when the mine is worked down to lower levels; for thoro-gummite is only an alteration product of mackintoshite, it having assumed one more molecule of water and changed its $UO_2$ to $UO_3$, and its color from an apparent jet-black mineral, of specific gravity 5·50, to a dull yellow-brown mineral having specific gravity 4·54+. Long square prisms, like those of zircon, with simple terminal pyramidal planes, were observed.

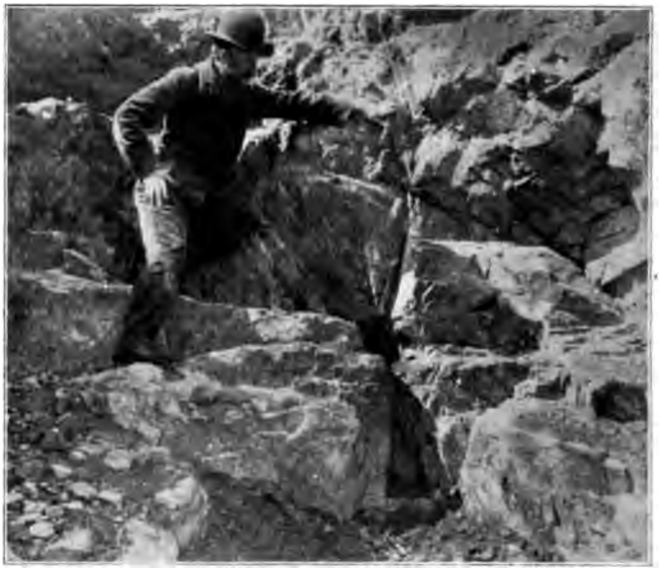
*Yttrialite.*—This species gave better radiographs from its altered red crust and its yellow ochreous variety than from the pure dark gray-green anhydrous mineral. All of its radio-activity must emanate from the ten to twelve per cent of thoria present. Hillebrand's last analysis has shown that its composition can best be interpreted by assuming that it is a mixture of an yttrium silicate with the thorite molecule (both anhydrous). Slabs of this mineral eight inches long and six inches broad were broken from some of the larger masses, thus affording fine opportunity for large experimentation in testing it radiographically.

*Fergusonite.*—The mono-hydrated variety made the best radiographs, but all the varieties (of which there are four at the locality) showed more or less action upon the sensitive film.

A new association was discovered in this species. Symmetrically compounded crystals of nivenite with fergusonite were found in the south walling of the hill. Long square prisms of nivenite with flat terminations, had in their centers an equally long but tapering pyramidal crystal of fergusonite, in parallel position. Some of these were one inch long and one-quarter inch thick. The fergusonite was of the purest kind and almost transparent, and somewhat resembled the famous Spanish sphalerite.

*Cyrtolite.*—Many hundred pounds were found and in great variety of form and color. All kinds of it gave good radiographs after twenty-four hours exposure. Plates of it as large as one's hand, covered on one side with curved crystals, were not rare. It sometimes encrusted large quartz crystals to the depth of one inch, having radiate structure, and thus afforded a new feature for this mineral and one very uncharacteristic of zircon.

4



*Radial Lines from the Ore Masses.*—As early as December of 1902, my attention was attracted to the strange occurrence of unusually long radial lines projecting in many directions from the bodies of ore richest in thorium, uranium and zirconium. I then named these occurrences "stars" and eagerly sought for them, as positive "pointers" to ore. At last I was obliged to give these "stars" more than passing attention and here state the reason: While removing, piece by piece, a seventy-pound mass of mixed zirconium-yttrium-uranium and thorium ore, which was a nucleus to one of the best marked of these "stars" (see fig. 4) from its quartz matrix, my hands and face would begin to burn as if from the effect of strong sunlight, and after two or three days of this kind of mining a redness of skin and a burning sensation would be followed by actual soreness of the parts of my hands and face exposed to the direct emanations from the minerals. My assistant (Mr. J. Edward Turner) complained of it also, and asked me "if these minerals could be poisonous?" As no arsenic was present, the soreness which we both experienced might possibly have been caused by free fluorine, but not by any soluble constituent of the mineral, since salts, such as would be dissolved by the moist skin, had long ago been dissolved, leached out and redeposited in the "chimney" of the mine. It was some time after this that the thought came to me that this action might be the work of a radio-active element and it is offered now more as a suggestion than as a proven fact. I incline strongly to the idea, however, of my having actually experienced the proof of the presence of a very high degree of radio-activity, of a peculiar if not unique kind, at this mine, and that the symptoms above described go a long way towards proving it. Of the true nature of this activity I will not at this time offer any conjectures, but will defer a discussion of it to a paper which is under preparation relating to this very interesting region.

Many photographic records were taken of these "stars," and one of them is shown in fig. 4; they are sometimes eight or ten feet across. Although these radial lines are not new to science, having often been noted elsewhere in connection with allanite, monazite and other rare species, it is not likely that they have been before observed on so large a scale. The cause of this phenomenon has not been determined, so far as I am informed, but it is not without interest that these radial lines are noted only with certain minerals containing rare elements and are most conspicuous with the radio-active species.

## ART. XLVI.—*A New Allotrope of Carbon and its Heat of Combustion*; by W. G. MIXTER.

[Contributions from the Sheffield Laboratory of Yale University.]

THE investigation of the carbon which separates when acetylene under pressure is exploded forms a part of the study of the thermal constants of the gas. The heat of formation of acetylene according to Thomsen is 47,700 calories; Berthelot's figures are 51,400 calories, and the writer by a direct determination obtained 53,300 calories for the heat of dissociation.* As these results vary so much it appeared desirable to investigate the thermal constants of the constituents of acetylene. The work on hydrogen has been published.† The writer concluded from the study of acetylene that the carbon from it would give a different heat of combustion from that of other forms of carbon. The results obtained confirm this view and indicate that acetylene carbon is a distinct allotropic form. The thermal effect of burning 12 grams of different kinds of carbon found by Favre and Silbermann, Berthelot, and the writer is as follows:

| Wood charcoal. | Sugar charcoal. | Gas retort carbon. | Graphite. | Diamond. | |
|---|---|---|---|---|---|
| 96,960$^c$ | 96,500$^c$ | 96,568° | 93,559$^c$ | 93,240$^c$ | Favre & Silbermann |
| 97,650$^c$ | | | 94,810$^c$ | 94,310$^c$ | Berthelot |
| | 96,700$^c$ | | 94,000$^c$ | | M. |

Acetylene carbon .......................... 94,728$^c$

The figures show that the carbon from acetylene is very different from the amorphous varieties of the charcoal type, and that its heat of combustion is nearly the same as that of graphite. Moissan has shown that it is not graphite, and does not contain graphite, as it does not yield graphitic acid on treatment with a mixture of potassium chlorate and fuming nitric acid, and my own test gave the same conclusive result.

The acetylene carbon as it comes from the bomb is a greyish black, lusterless and very bulky, porous mass. When compressed it has a brilliant black luster, but not the metallic appearance of graphite. It is a good conductor of heat and electricity. While one gram condenses one milligram of dry air on its surface and in the pores, it does not exert catalytic action on the gases of decay in presence of air, such as we are familiar with in case of charcoal. When a mixture of acetylene carbon and sulphuric acid is boiled no odor of sulphur dioxide is perceptible, but the escaping vapors turn a blue iodide of starch paper white. Dense sugar charcoal decomposes the hot acid readily. Acetylene carbon absorbs only about, 1/10 of 1 per cent of its weight of moisture from the air, differing in this respect from charcoal. The determination of density was made as follows: The carbon of the second series of experiments was placed in absolute alcohol, which was then boiled to expel air; ethylene bromide was next added and the boiling repeated. By successive additions of alcohol and bromide a liquid was obtained in which the carbon remained suspended over night. Professor Penfield kindly determined on a Westphal balance the density of this liquid and found it to be 1·919 at common temperature.

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* This Journal, xii, 347.

† This Journal, xvi, 214.

### *First Series of Experiments.*

The bomb used for this part of the work was the one described in this Journal, xii, 347, but with the addition of a long narrow neck. Two determinations of the water equivalent of the calorimeter at 20° gave 285 and 281·2 grams and the equivalent calculated from the specific heats of the metals was 284·7 grams. Since the fittings of the calorimeter varied somewhat in the different experiments, the figures for the water equivalent vary slightly. The carbon in a loose bulky mass in the bottom of the bomb was ignited by the glowing magnetic oxide which dropped into it when the iron wire attached to the platinum electrodes was ignited by an electric current. The combustion was explosive in character and complete, and gave a temperature that fused the ends of the thick platinum wires. The thermometer would rise perceptibly in three seconds after passing the electric current. The oxygen used was made from potassium chlorate and collected in a glass gas holder over a dilute solution of potassium hydroxide. In order to have the bomb fairly free from nitrogen it was repeatedly exhausted and filled with oxygen and then the gas was pumped in until the pressure was between 10 and 15 atmospheres. The weight of the oxygen was found by weighing the bomb before and after filling it with the gas.

In the first three experiments the silver plating protected the steel from oxidation, and the silver dissolved by the nitric acid formed was not determined. For the remaining tests the bomb was lined with a tight fitting shell of silver $1^{mm}$ in thickness, and the silver dissolved was precipitated and weighed as chloride. The heat of burning 1 mlg. of iron was considered to be 1·6 calory.

The air condensed on the surface of the carbon in the loose form in which it was weighed for the various experiments was found as follows:

A cylindrical glass vessel with a long neck and stopcock and having a capacity of $67^{cc}$ was filled with 3 grams of acetylene carbon. It was exhausted and heated for an hour to about 400° and then allowed to cool and the stopcock closed, the mercury pump being in action all the time. Next it was counterpoised by a similar vessel and the needed weights, and finally dry air was admitted and the increase in weight observed. The data required are the weight and density of the carbon, the capacity of the vessel, the weight of the air admitted, the temperature and barometric pressure. The results of three determinations were 3·2, 3·4, and 3·1 milligrams of air condensed by 3 grams of the carbon. The apparatus was crude and the result is to be regarded merely as proving that but little air is condensed by the carbon.

The carbon for the first series of tests was from the sample obtained three years ago in the determination of the heat of dissociation of acetylene.* It contained a little incombustible matter or ash derived from the bomb and the impurities of the gas from which it was made. The composition of it was found as follows: The carbon was compressed in a large platinum tray open at one end and nearly closed on top and the tray and contents were placed in a long narrow platinum crucible with a close-fitting cover and heated to redness. After cooling over sulphuric acid the whole was weighed, then heated again, allowed to cool as before and then the weight was quickly taken. With these precautions the error due to moisture is negligible. The observed weight was corrected for ash, absorbed air and reduced to weight in vacuum. The combustion was made with oxygen and oxide of copper. The water was absorbed in a U-tube filled with beads drenched with sulphuric acid and the carbon dioxide by a solution of potassium hydroxide in a helical tube, the unabsorbed gas passing through a U-tube filled with solid potassium hydroxide and then through another tube containing beads drenched with sulphuric acid. To the last tube there was an attachment to keep out moisture. Each piece of absorption apparatus was counterpoised on the balance by a similar one to eliminate the effects of atmospheric changes. For each gram of carbon dioxide 0·5 of a milligram was added for reduction to weight in vacuum. This was the correction calculated for the solution of potassium hydroxide used which had a density of 1·38; it was also found by experiment to be the same. The calculations are based on the atomic weights 12 and 16 of carbon and oxygen respectively. The following are the results:

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* Loc. cit.

| | I. | II. | Mean. |
|---|---|---|---|
| Acetylene carbon taken | 1·1485 | 1·3838 gram | |
| Carbon | 99·93 | 99·96 | 99·95 per cent |
| Hydrogen | 0·04 | 0·03 | 0·03 " |

The weight of the substance, corrected as already described, multiplied by 0·9995 was taken to be the amount of carbon burned in the calorimeter. The specific heat of both oxygen and carbon dioxide at constant volume is very nearly 0·15. Hence the product of this number by the total weight of the carbon and oxygen is included in the water equivalent of the calorimetric system. The observed weight of the water in the calorimeter was reduced to weight in vacuum. The temperature observed the instant before an explosion was taken as the initial temperature and it was assumed that the gain and loss of heat were equal during the first minute after an explosion, and correction was made for the loss during the four minutes following. Thermometer No. 172863, described in the paper on "The Heat of Combustion of Hydrogen,"* was used in this first series of experiments.

*Experiment 1.*—Carbon 1·3740, hydrogen 0·0004, iron 0·070, oxygen 10·2 grams.

| | | |
|---|---|---|
| Water | 2190· | grams |
| Water equivalent of calorimeter | 258·6 | " |
| " " carbon dioxide and oxygen | 1·7 | " |
| | 2450·3 | " |

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·700 | | |
| 1 | 18·700 | 23·124—18·7+0·04 = | 4·464° |
| 2 | 22·5 | | |
| 3 | 23·115 | Heat observed, 2450·3×4·464 = | $10938^c$ |
| 4 | 23·139 | " of oxidation of iron | $-112^c$ |
| 5 | 23·133 | " " " hydrogen | $-14^c$ |
| 6 | 23·124 | | |
| 7 | 23·113 | | $10812^c$ |
| 8 | 23·102 | | |
| 9 | 23·092 | For 1 gram of carbon | $7869^c$ |

The water with which the bomb was washed after the experiment was free from silver.

*Experiment 2.*—Carbon 1·0318, hydrogen 0·0003, iron 0·030, oxygen 10·5, water and water equivalent 2543·4 grams.

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* This Journal, xvi, 214.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·426 | | |
| 1 | 18·430 | 21·669 − 18·442 + 0·009 = | 3·236° |
| 2 | 18·434 | | |
| 3 | 18·437 | Heat observed, 2543·4 × 3·236 = | 8230·6$^{c}$ |
| 4 | 18·442 | " of oxidation of iron | −48·$^{c}$ |
| 5 | 21·4 | " " " hydrogen | −10·2$^{c}$ |
| 6 | 21·672 | | ——— |
| 7 | 21·672 | | 8172·4$^{c}$ |
| 8 | 21·672 | For 1 gram of carbon | 7919·5$^{c}$ |
| 9 | 21·669 | | |
| 10 | 21·666 | The slight amount of silver dissolved was not determined. | |
| 11 | 21·664 | | |
| 12 | 21·661 | | |
| 13 | 21·659 | | |
| 14 | 21·657 | | |

*Experiment 3.*—Carbon 1·1136, hydrogen 0·0003, iron 0·030, oxygen 10·5, water and water equivalent 2599·6 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·843 | | |
| 1 | 18·845 | 22·230 − 18·851 + 0·02 = | 3·399° |
| 2 | 18·847 | | |
| 3 | 18·849 | Heat observed, 2599·6 × 3·399 | 8836·1$^{c}$ |
| 4 | 18·851 | " of oxidation of iron | −48·$^{c}$ |
| 5 | 21·95 | " " " hydrogen | −11·$^{c}$ |
| 6 | 22·231 | | ——— |
| 7 | 22·238 | | 8777·1$^{c}$ |
| 8 | 22·235 | For 1 gram of carbon | 7881·7$^{c}$ |
| 9 | 22·230 | | |
| 10 | 22·226 | | |
| 11 | 22·221 | | |
| 12 | 22·216 | | |

In the next three experiments a larger german silver calorimeter can was used and the bomb was lined with pure silver as already described.

*Experiment 4.*—Carbon 1·2688, hydrogen 0·0004, iron 0·050, oxygen 10, water and water equivalent 3434·8 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·381 | 21·315 − 18·381 + 0·018 = | 2·952° |
| 1 | 18·381 | | |
| 2 | 18·381 | Heat observed, 3434·8 × 2·952 = | 10139·6$^{c}$ |
| 6 | 21·309 | " of oxidation of iron | −80·$^{c}$ |
| 7 | 21·315 | " " " hydrogen | −13·6$^{c}$ |
| 8 | 21·312 | " of formation of silver nitrate | −18·4$^{c}$ |
| 9 | 21·307 | | ——— |
| 10 | 21·302 | | 10027·6$^{c}$ |
| 11 | 21·297 | For 1 gram of carbon | 7903·4$^{c}$ |
| 12 | 21·292 | | |

According to Thomsen* the thermal effect of the formation from its elements of $Ag_2N_2O_6$ and solution in water is 46,600 calories. From which we find that 1 mlg. of silver dissolved corresponds to 0·216$^c$. The solution from the interior of the bomb after an explosion in no instance reacted acid to ordinary litmus paper, showing that the nitric acid was mostly taken up by the silver. In experiment 4, 85·4 mlgs. of silver were found in rinsings, showing 18·4$^c$ were due to the oxidation of nitrogen and solution of silver.

*Experiment 5.*—Carbon 1·3054, hydrogen 0·0004, iron 0·0385, silver dissolved 0·0726, oxygen 10·2, water and water equivalent 3302·2 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·958 | | |
| 1 | 18·958 | 22·083 − 18·958 + 0·021 = | 3·146° |
| 2 | 18·958 | | |
| 3 | 21·8 | Heat observed, 3302·2 × 3·146 = | 10388·7$^c$ |
| 4 | 22·079 | " of oxidation of iron | −61·6$^c$ |
| 5 | 22·092 | " " hydrogen | −13·6$^c$ |
| 6 | 22·088 | " formation of silver nitrate | −15·7$^c$ |
| 7 | 22·083 | | |
| 8 | 23·077 | | 10297·8$^c$ |
| 9 | 22·073 | For 1 gram of carbon | 7888·8$^c$ |
| 10 | 22·067 | | |
| 11 | 22·062 | | |
| 12 | 22·055 | | |
| 13 | 22·051 | | |

*Experiment 6.*—Carbon 1·3277, hydrogen 0·0004, iron 0·040, silver dissolved 0·0918, oxygen 9·7, water and water equivalent 3253·9 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·894 | | |
| 1 | 18·896 | 22·135 − 18·9 + 0·014 = | 3·249° |
| 2 | 18·898 | | |
| 3 | 18·900 | Heat observed, 3253·9 × 3·249 = | 10572·$^c$ |
| 4 | 21·9 | " of oxidation of iron | − 64·$^c$ |
| 5 | 22·129 | " " " hydrogen | − 13·6$^c$ |
| 6 | 22·139 | " formation of silver nitrate | − 19·8$^c$ |
| 7 | 22·137 | | |
| 8 | 22·135 | | 10474·6$^c$ |
| 9 | 22·131 | For 1 gram of carbon | 7889·4$^c$ |
| 10 | 22·127 | | |
| 11 | 22·124 | | |
| 12 | 22·121 | | |
| 13 | 22·117 | | |
| 14 | 22·114 | | |
| 15 | 22·111 | | |
| 16 | 22·108 | | |

The gas in the bomb after the calorimetric test was transferred to a gas holder containing a solution of caustic potash and was left several hours to ensure the complete absorption of carbon dioxide. It was then passed into a solution of barium hydroxide and over glowing copper oxide, and finally through a clear solution of barium hydroxide. The barium solutions remained clear. In the delivery tube in the second there was a faint white ring indicating that the gas contained a trace of carbonic oxide. The same result was obtained in subsequent experiments and is what might be expected in a cooling mixture of oxygen, carbon dioxide and carbonic oxide formed directly from the burning of the carbon and by the dissociation of carbon dioxide by heat. The amount of carbonic oxide remaining in the bomb was, however, too small to be estimated by ordinary methods or to have an appreciable influence on the thermal result.

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* Thermo-Chem. Untersuchen, iii, p. 282.

The mean of the foregoing results is 7892· calories for one gram of carbon. This is considerably less than other investigators found for amorphous carbon and not much higher than obtained for graphite. In order to find if the variation was due to a constant error, sugar charcoal and graphite were burned in the apparatus used for experiments 4, 5 and 6.

### *Sugar Charcoal.*

The charcoal was prepared by charring sugar and heating the coal for several hours in a Perrot furnace: next it was heated for two hours in a current of chlorine, and finally it was kept at a white heat for six hours. The product contained a trace of chlorine and 1/10 of 1 per cent of ash. The carbon and hydrogen were determined with the precautions already described. The following results are for the ash-free coal:

| | I. | II. | Mean. |
|---|---|---|---|
| Carbon | 99·08 | 99·04 | 99·06 |
| Hydrogen | 0·13 | 0·13 | 0·13 |
| Oxygen ? | .... | .... | (0·81) |
| | | | 100·00 |

The thermal results obtained, less the heat of combustion of the hydrogen content, were 8028, 8023 and 8027, mean 8026 calories for one gram of carbon. Considering that 0·81 per cent of the charcoal is oxygen in combination with hydrogen we have 8057 calories. Neither method of allowing for the hydrogen is to be considered as accurate, and the first correction is excessive.

### *Graphite.*

Compact crystalline graphite associated with calcite was pulverized, digested with hydrochloric acid and washed. Thus purified it contained 0·32 per cent of ash. The analysis of the combustible portion gave

| | I. | II. |
|---|---|---|
| Carbon | 99·90 | 99·89 |
| Hydrogen | 0·01 | 0·02 |

The graphite is probably free from hydrogen as the amount given above is within the limits of error. Three calorimetric tests, using for each about 1·6 gram, gave 7836, 7848 and 7810, mean 7831 calories for the heat of combustion of one gram of graphite.

### *Second Series of Experiments.*

The carbon for this series was prepared as follows: Acetylene gas from carbide was passed through a long tube containing solid potassium hydroxide then pumped into the bomb through another tube two meters in length filled with fragments of potassium hydroxide. The one to two per cent impurity in the gas was chiefly nitrogen and oxygen. A little phosphureted hydrogen was also present. The gas at an initial pressure of about 10 atmospheres was fired by an electric spark between the neck of the bomb and the valve. The thermal effects for one gram of acetylene in four tests were 2063, 2080, 2075 and 2070, mean 2072 calories. This is 32 calories higher than the result obtained in the work* which yielded the carbon used in the first series of experiments. The hydrogen gas remaining after the explosion was free from acetylene but contained a little hydrocyanic acid.

The carbon was tested for hydrogen as follows: Two blank trials of the combustion apparatus were made using about 4 liters of oxygen and air in each. The sulphuric-acid absorption tube before the combustion tube gained 1·2 and 1·3 mlgs., and the one at the other end 2·1 and 0·6 mlgs., respectively, in the two tests. Then 2·11 grams of the carbon which had been heated to redness and cooled in a desiccator were placed in the combustion tube, and heated for a time in a current of dry air to drive off any water present. Next the absorption tubes were connected and the combustion was made in the usual way. The anterior tube gained 1·3 mlg. and the one through which the products passed gained 4·2 mlgs. The cause of the increase of the anterior tube was not evident. The oxygen and air used were dried by caustic potash and calcium chloride and then passed through a long U-tube filled with beads drenched with the same sulphuric used in the weighed tubes. It is evident that the gain of 4·2 mlgs., equivalent to 0·02 per cent of hydrogen, may be due to something other than water formed in the combustion of the substance, and we may assume that the carbon was either free from hydrogen or contained too little to be considered in the calorimetric results.

The carbon was repeatedly digested with a mixture of nitric acid, density 1·57, and potassium chlorate and was finally completely oxidized, leaving, however, a few minute transparent particles. When it was oxidized in other ways similar particles were found.

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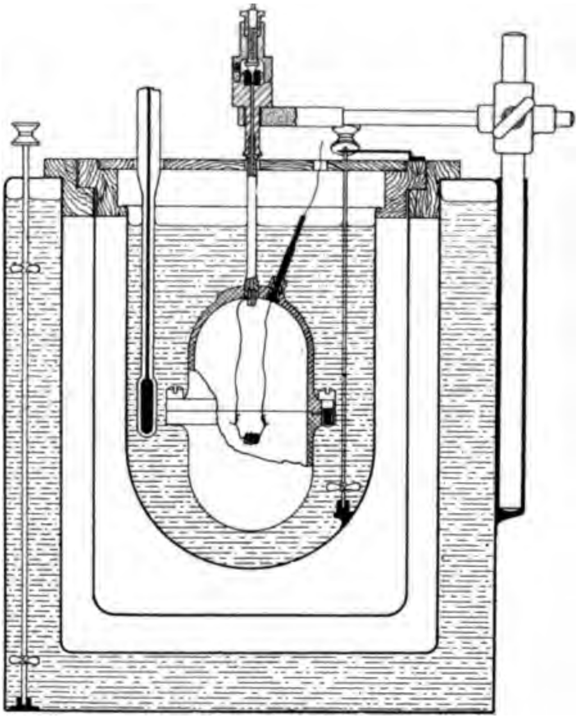
* Loc. cit.

The calorimeter used in this second series of experiments is shown in the figure. The bomb was silver plated and lined with pure silver a millimeter in thickness. The water equivalent of the calorimeter is less than one-tenth of the water it contained. Thermometer No. 1, described in the paper on hydrogen (loc. cit.) was used.



*Experiment 1.*—

| | | | |
|---|---|---|---|
| Observed weight of carbon ...... .. | | 1·5057 | gram |
| Air condensed on " ........ | — | 0·0017 | " |
| Reduction for weight in vacuum.. | + | 0·0008 | " |
| Corrected weight ................ | | 1·5048 | " |
| Observed weight of water .......... | | 3255·5 | grams |
| Reduction for weight in vacuum .... | | 3·2 | " |
| Water equivalent of oxygen and carbon dioxide ................... | | 1·7 | " |
| Water equivalent of calorimeter..... | | 286·6 | " |
| Water and water equivalent ........ | | 3547 | " |
| Oxygen ........................ | | 9·7 | " |
| Iron wire to ignite the carbon.......... | | 44 | milligrams |
| Silver dissolved by $HNO_3$ formed....... | | 38 | " |

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 18·421 | | |
| 1 | 18·426 | 21·811—18·436+0·007 = 3·382° | |
| 2 | 18·431 | | |
| 3 | 18·436 | | |
| 4 | 21·8 | | |
| 5 | 21·810 | Heat observed, 3547×3·382 = | 11996$^{c}$ |
| 6 | 21·816 | " of oxidation of iron | — 70·4$^{c}$ |
| 7 | 21·813 | " of formation of silver nitrate | — 8·2$^{c}$ |
| 8 | 21·811 | | ——— |
| 9 | 21·809 | Heat of combustion of 1·5048 | |
| 10 | 21·807 | gram of carbon | 11917.4$^{c}$ |
| 11 | 21·805 | Heat of combustion of 1 gram | |
| 12 | 21·803 | of carbon | 7919·6$^{c}$ |
| 13 | 21·802 | | |
| 14 | 21·801 | | |
| 15 | 21·399 | | |

*Experiment 2.*—Carbon 1·4304, iron 0·040, silver dissolved 0·048, oxygen 10·5, water and water equivalent, 3637·6 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 19·263 | | |
| 1 | 19·268 | 22·394—18·272+0·003 = 3·125° | |
| 3 | 19·272 | | |
| 4 | 22· | Heat observed, 3637·6×3·125 = | 11367·5$^{c}$ |
| 5 | 22·39 | " of oxidation of iron | —64· $^{c}$ |
| 6 | 22·395 | " of formation of silver nitrate | —10·4$^{c}$ |
| 7 | 22·394 | | ——— |
| 8 | 22·392 | | 11293·1$^{c}$ |
| 9 | 22·392 | For 1 gram of carbon | 7895· $^{c}$ |
| 10 | 22·392 | | |
| 11 | 22·391 | | |
| 12 | 22·390 | | |
| 13 | 22·389 | | |
| 14 | 22·388 | | |

*Experiment 3.*—Carbon 1·5354, iron 0·031, silver dissolved 0·064, oxygen 10·6, water and water equivalent 3618 grams.

| Minutes. | Temperature. | Temperature interval. | |
|---|---|---|---|
| 0 | 19·104 | | |
| 1 | 19·108 | 22·466—19·112+0·010 = 3·364° | |
| 2 | 19·112 | | |
| 3 | 22·25 | Heat observed, 3618×3·364 = | 12171 $^{c}$ |
| 4 | 22·472 | " of oxidation of iron | —49·6$^{c}$ |
| 5 | 22·472 | " of formation of silver nitrate | —13·6$^{c}$ |
| 6 | 22·470 | | ——— |
| 7 | 22·466 | | 12107·8$^{c}$ |
| 8 | 22·463 | For 1 gram of carbon | 7885·7$^{c}$ |
| 9 | 22·461 | | |
| 10 | 22·458 | | |
| 11 | 22·456 | | |
| 12 | 22·454 | | |
| 13 | 22·451 | | |
| 14 | 22·449 | | |

*Experiment 4.*—Carbon 1·361, iron 0·032, silver dissolved 0·013, oxygen 10·5, water and water equivalent 3511·5 grams.

| Minutes. | Temperature. | Temperature interval. |
|---|---|---|
| 0 | 18·777 | |
| 1 | 18·780 | 21·848—18·786+0·008 = 3·070° |
| 2 | 18·783 | |
| 3 | 18·786 | Heat observed, 3511·5×3·07 = 10780·3$^c$ |
| 4 | 21·8 | " of oxidation of iron −51·2$^c$ |
| 5 | 21·853 | " of formation of silver nitrate — 2·7$^c$ |
| 6 | 21·853 | |
| 7 | 21·851 | 10726·4$^c$ |
| 8 | 21·848 | For 1 gram of carbon 7881·3$^c$ |
| 9 | 21·845 | |
| 10 | 21·843 | |
| 11 | 21·841 | |
| 12 | 21·839 | |
| 13 | 21·838 | |

### *Summary of Results.*

| Experiment No. | First series. | Second series. |
|---|---|---|
| 1 | 7869 | 7919·6 |
| 2 | 7919·5 | 7895 |
| 3 | 7881·7 | 7885·7 |
| 4 | 7903·4 | 7881·3 |
| 5 | 7888·8 | |
| 6 | 7889·4 | |
| Average | 7892· | 7895·4 |

The mean of the results of the two series of experiments is 7894 calories for the heat of combustion of one gram of acetylene carbon at constant pressure and volume and at about 20° and in terms of the water calorie at this temperature, and for 12 grams it is 94,728 calories.

## ART. XLVII.—*Reflection of Light by Colored Papers*; by HOWARD D. MINCHIN.

ALTHOUGH the subject of reflection of light by various surfaces has received much attention, the question of the reflecting power of colored papers and of wall papers in particular seems to have attracted little notice. The importance of the subject from an economic as well as from an artistic standpoint would seem to justify the attempt to settle certain features in the question even though the treatment be little more than qualitative.

The investigation is complicated at the outset by our inability to specify definitely the exact sample of paper under examination as well as by our inability to reproduce such sample for purposes of subsequent comparison and measurement. Nevertheless it has been thought worth while to submit the result of a series of measurements upon the reflective powers of a set of ordinary commercial papers.

Under the head of metallic reflection the classic investigation of Hagen and Rubens,* Langley,† Nichols,‡ Jamin,§ Quincke,‖ and Drude,¶ are of the first importance. Wright,** studied diffuse reflection of light on matt surfaces, while the reflective powers of mercury and glass were investigated by Walbott,†† and Walker,‡‡ respectively. Investigations touching the reflection of light by colored papers are, so far as known to the author, confined to the writings of Abney,§§ Abney and Festing,‖‖ and of Kononowitsch,¶¶ but in none of these can be found any mention of the subject under consideration.

### *Apparatus and Method.*

The measurements of the investigation here discussed were made by means of a Brace spectrophotometer consisting of two collimators T and T′, a telescope A, and a Brace prism P (fig. 1). The sources of light were two 220 volt 16 candle power incandescent lamps. One was permanently fixed at

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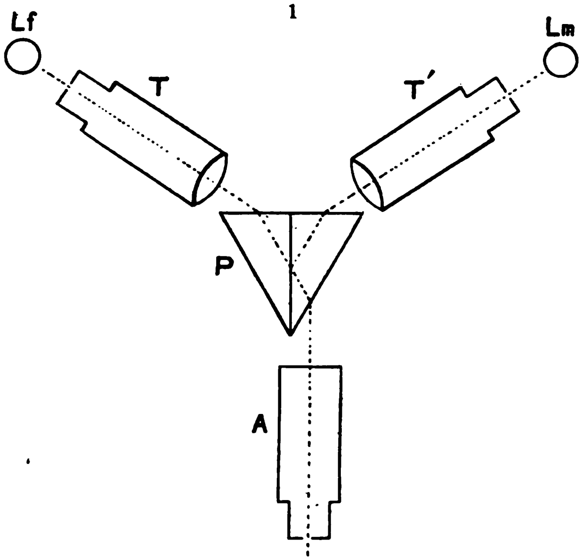
* Hagen and Rubens, Ann. d. Physik., i, 352, 1900.
† S. P. Langley, Phil. Mag., xxvii, 10, 1889.
‡ E. L. Nichols, Wied. Ann., lx, 401, 1897.
§ J. Jamin, Ann. Chim. Phys. (3), xxii, 311, 1848.
‖ G. Quincke, Pogg. Ann. Jubelb'd., 336, 1874.
¶ P. Drude, Wied. Ann., xxxix, 481, 1890.
** H. R. Wright, Phil. Mag. (5), xlix, 199, 1900.
†† H. Walbott, Wied. Ann., lxviii, 471, 1899.
‡‡ B. Walker, Wied. Ann., lii, 762, 1894.
§§ Abney, Roy. Soc. Proc., lxvii, 118, 1900.
‖‖ Abney and Festing, Phil. Trans., clxxii, 887, 1882.
¶¶ Kononowitsch, Wied. Ann., lxvi, 317, 1897.

1

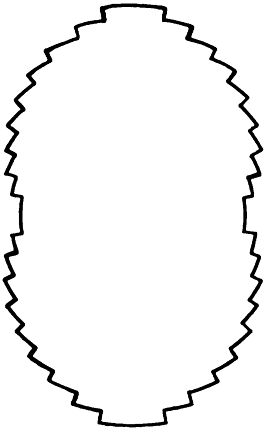


collimator T, in which the slit was adjusted to some desired width. The second lamp was used at collimator T′, first directly in front of the slit and afterwards at one side, the light from it being reflected into T′ by the reflecting surface. Care was taken so to shield the lamps that no light reached the prism P, except that coming through the slits. To obtain a more uniform field ground glass plates were placed directly in front of the slits.

A revolving disk (fig. 2) similar to that described by Brace* was placed in front of T, by means of which the intensity of the light admitted to the slit could be varied by tenths, giving 0·1, 0·2, 0·3, etc., of the full intensity. The disk was driven by an electric motor as described by Murphy.†

With the lamps placed directly in front of the two collimators and the slit in collimator T set at a definite width, the slit in T′ was calibrated by means of the rotating disk, according to the method described by Capp,‡ for the five colors:

2



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* Brace, Astro-Physical Journal, xi, 6.
† Murphy, " " " vi, 5.
‡ Capp, " " " vii, 25.

red, $\lambda = 0{\cdot}0006562^{mm}$
yellow, $\lambda = 0{\cdot}0005893^{mm}$
green, $\lambda = 0{\cdot}0005460^{mm}$
blue, $\lambda = 0{\cdot}0004862^{mm}$
violet, $\lambda = 0{\cdot}0004357^{mm}$

The slit in T′ was adjusted for a match first with the total light admitted at T, then with 0·5, 0·3, 0·2, and 0·1, the total light.

3

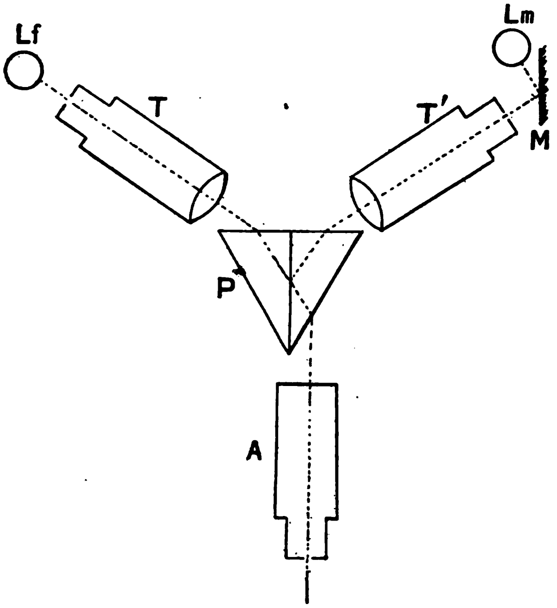

Table I gives the required width of T′ in mm. for a match in the different colors when T is $0{\cdot}2^{mm}$ in width. All values recorded are the average of eight readings. *Data:*

TABLE I.

Width of T′ in mm.

| Color. | For intensities of | | | | |
|---|---|---|---|---|---|
| | 1·0 | 0·5 | 0·3 | 0·2 | 0·1 |
| Red ...... | 0·263 | 0·146 | 0·095 | 0·071 | 0·041 |
| Yellow ... | 0·293 | 0·165 | 0·099 | 0·079 | 0·042 |
| Green .... | 0·307 | 0·171 | 0·105 | 0·082 | 0·046 |
| Blue ..... | 0·334 | 0·183 | 0·118 | 0·090 | 0·055 |
| Violet .... | 0·368 | 0·189 | 0·103 | 0·105 | 0·048 |

The lamp at T′ was next placed at one side and a mirror fixed at T′ to reflect the light into the slit. Fig. 3 shows the arrangement.

The length of the light path was kept constant and the angle of incidence was made 45°. The results are given in Table II.

TABLE II.

Width of T′ when mirror is used.

| Color. | Intensities at T. | | | |
|---|---|---|---|---|
| | 1·0 | 0·5 | 0·3 | 0·1 |
| Red | 0·569 | 0·276 | 0·190 | 0·081 |
| Yellow | 0·607 | 0·305 | 0·198 | 0·084 |
| Green | 0·621 | 0·332 | 0·209 | 0·091 |
| Blue | 0·685 | 0·381 | 0·238 | 0·109 |
| Violet | 0·810 | 0·392 | 0·204 | 0·094 |

The colored paper was substituted for the mirror and adjustments of T′ made as before. The following tables give the results for the paper used:

(The interrogation point denotes some light, but not sufficient for a match. 0 means no trace of color noticeable.)

Width of T′ when T = ·1$^{mm}$.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Deep red | Red | 1·287 | 1·878 | 2·697 | ? | .. |
| | Yellow | ? | .... | .... | .. | .. |
| | Green | ? | .... | .... | .. | .. |
| | Blue | ? | .... | .... | .. | .. |
| | Violet | 0 | 0 | 0 | 0 | 0 |

Width of T′ when T = 0·2$^{mm}$.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Light red | Red | 0·460 | 0·889 | .. | 1·680 | 2·009 |
| | Yellow | ? | .... | .. | .... | .... |
| | Green | * | .... | .. | .... | .... |
| | Blue | 2·235 | .... | .. | .... | .... |
| | Violet | ? | .... | .. | .... | .... |

Width of T′ when T = 0·2$^{mm}$.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Dark green | Red | 1·903 | ? | .. | .. | .. |
| | Yellow | 2·650 | ? | .. | .. | .. |
| | Green | 1·810 | ? | .. | .. | .. |
| | Blue | 2·122 | ? | .. | .. | .. |
| | Violet | 2·418 | ? | .. | .. | .. |

* When T′ was narrow a little green was seen, but when T′ was widened for a match all trace of green disappeared.

Width of T′ when T = 0·1mm.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Dull green | Red | 1·424 | ? | -- | -- | -- |
| | Yellow | 1·302 | ? | -- | -- | -- |
| | Green | 1·056 | 2·091 | ? | -- | -- |
| | Blue | 1·450 | 2·278 | ? | -- | -- |
| | Violet | ? | ---- | -- | -- | -- |

Width of T′ when T = 0·1mm.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Light green | Red | 1·289 | 2·120 | ? | ---- | ---- |
| | Yellow | 1·176 | 2·204 | ? | ---- | ---- |
| | Green | 0·683 | 1·299 | 2·029 | ? | ---- |
| | Blue | 0·782 | 1·280 | 1·912 | 2·129 | 2·710 |
| | Violet | Just a slight trace | | | | |

Width of T′ when T = 0·2mm.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Dark blue | Red | 1·847 | ? | -- | -- | -- |
| | Yellow | ? | -- | -- | -- | -- |
| | Green | ? | -- | -- | -- | -- |
| | Blue | 4·667 | -- | -- | -- | -- |
| | Violet | ? | -- | -- | -- | -- |

Width of T′ when T = 0·1mm.

| Paper. | Color reflected. | Intensities at T. | | | | |
|---|---|---|---|---|---|---|
| | | 0·1 | 0·2 | 0·3 | 0·4 | 0·5 |
| Light blue | Red | 1·213 | 2·061 | ? | ---- | ---- |
| | Yellow | 1·088 | 1·980 | ? | ---- | ---- |
| | Green | 0·936 | 1·684 | 2·521 | ? | ---- |
| | Blue | 0·789 | 1·505 | 2·096 | ? | ---- |
| | Violet | 1·036 | 1·111 | 1·631 | 2·117 | 2·886 |

## *Discussion of Data.*

Table II shows that approximately one half the incident light was reflected by the mirror. Both Table I and Table II show that as the violet end of the spectrum was approached the width of T′ had to be increased to procure a match.

Because of the small amount of light reflected by the papers it became necessary to cut down the intensity of the light admitted at T. Each of the tables gives the greatest intensities that could be used and allow the obtaining of a match.

The deep red paper reflected red light only, to a sufficient degree to allow of a match.

The intensity of the light reflected by the light red paper was very low and it was necessary to narrow T to 0·1$^{mm}$. A match was then obtained for red and blue.

The green papers reflected all colors in considerable amounts. The dark green reflected red and green light about equally, while the light green reflected less of the red and reflected green and blue in about the same amounts, but as the intensity of the light admitted at T was increased more blue than green was reflected.

The dark blue paper reflected red light of an intensity about two and one-half times the intensity of the blue reflected. The other colors were reflected in very small amounts.

With the light blue paper all the colors were reflected when the intensity at T was 0·1 or 0·2, and with intensities at T of 0·4 and 0·5 a match was obtained with violet light only.

A comparison of all the papers used can be made only for an intensity of light admitted at T of 0·1. The following table gives the width of T′ in terms of T for a match in the different colors. For example, in the red when light was admitted directly, T′ was 0·21 times the width of T for match, when the mirror was used T′ was 0·41 times the width of T, etc.

T′ in terms of T.

| Light from. | Colors. | | | | |
|---|---|---|---|---|---|
| | Red. | Yellow. | Green. | Blue. | Violet. |
| Direct | 0·21 | 0·21 | 0·23 | 0·28 | 0·24 |
| Mirror | 0·41 | 0·42 | 0·46 | 0·55 | 0·47 |
| Deep red | 6·44 | ? | ? | ? | ? |
| Light red | 4·60 | ? | ? | 22·34 | ? |
| Dark green | 9·52 | 13·25 | 9·05 | 15·61 | 12·09 |
| Dull green | 14·24 | 13·02 | 10·56 | 14·50 | ? |
| Light green | 12·89 | 11·76 | 6·83 | 7·82 | ? |
| Dark blue | 9·24 | ? | ? | 23·34 | ? |
| Light blue | 12·13 | 10·88 | 9·36 | 7·89 | 10·36 |

The dark green and the light blue papers are the only papers that reflected all colors sufficiently to obtain a match. The light green and the dull green papers are the next in order, both the latter reflected very little violet light. The light reflected by the dark green and the light blue papers is more nearly white light than that from any of the other papers used.

*Less than 0·02 of the incident light was reflected by the best paper used, when all conditions were the best possible.*

The observations embodied in this paper were made in the Physical Laboratory of the University of Michigan, at the suggestion of Professor Reed, to whom thanks are due for his interest and assistance during the progress of the investigation.

**Physical Laboratory, University of Rochester, January, 1905.**

# SCIENTIFIC INTELLIGENCE.

## I. CHEMISTRY AND PHYSICS.

1. *New Experiments in Preparing Diamonds.*—In his examination of the Canyon Diablo meteorite, **MOISSAN** noticed that the diamonds found in it occurred in fissures containing sulphide of iron, and it seemed possible that sulphur might have had an influence in the formation of these crystals. He has, therefore, made some new experiments upon the formation of diamonds by crystallization from iron saturated with carbon in the electrical furnace and rapidly cooled with water, and has modified his experiments of several years ago by additions of sulphide of iron, silicide of iron, or phosphide of iron to the fused metal before cooling. The results showed that the production of diamonds was somewhat better in the presence of sulphur than had formerly been the case without this addition, and silicon appeared also to exert a favorable influence, but in this case more difficulty was encountered in the separation of the diamonds from the ingot, on account of the presence of carbide of silicon. No diamonds were obtained in two experiments where phosphide of iron was added. Some of the diamonds produced in the presence of sulphur were large enough to be separated with the naked eye by means of a steel point, while the largest of those made in the presence of silicon had a length of $\cdot 75^{mm}$. Their size is of the same order as that of those from the meteorite, and they are practically microscopic objects. Moissan has confirmed his previous conclusion that the artificial substance is actually diamond, and he finds that, like the natural substance, it often shows weak double refraction. He regards the diamond as a form of carbon which has been liquefied under high pressure, since he has shown previously that at ordinary pressure all forms of carbon vaporize without becoming liquid, and all produce graphite.—*Comptes Rendus*, cxl, 277. H. L. W.

2. *Atomic Weights of Sodium and Chlorine.*—T. W. **RICHARDS** and R. C. **WELLS** have made a very elaborate investigation in revising these important atomic weights. As is usual with the work of Richards, the greatest precautions have been taken in purifying materials, detecting sources of error and avoiding or making accurate allowances for them, and in the use of varied methods and materials. The description of the work inspires the utmost confidence in it, as well as admiration for the skill and patience displayed in carrying it out. As a result of their research it appears that the work of Stas on the atomic weights in question was slightly erroneous. From a study of the ratios AgCl : NaCl, Ag : NaCl, and Ag : AgCl, they find that when the atomic weight of silver is taken as 107·930, sodium is 23·008, and chlorine is 35·473, whereas the previously accepted numbers are 23·05 and 35·45. Many other atomic weights are affected, in

their second decimal places, by these changes, and a recalculation of the atomic weights will be necessary soon. Richards suggests, however, that this systematic recalculation be delayed until a few other new data should have been obtained—in particular, new analyses of potassium chloride, silver chlorate, the bromides, sulphides and sulphates, and similar important compounds. Some of these are already being made, and others will be undertaken at once by Professor Richards.—*Carnegie Institution of Washington.* Publication No. 28. H. L. W.

3. *The Origin of Radium.*—A continuation of the investigations of Dr. B. B. Boltwood upon the relative quantities of uranium and radium in various minerals, an account of which appeared in the preceding volume of this Journal, shows that these quantities are proportional to one another, within the limits of experimental errors, even in minerals containing much thorium and very small amounts of uranium. The more recent experiments were the examination of twenty-two specimens of minerals where the accurately determined percentages of uranium vary from 74 to 0·3 per cent, and in this series allowance is made for the emanation lost at ordinary temperatures by the various samples. The author says that the inevitable and only possible conclusion from the results is that uranium is the parent of radium, and that the participation of thorium in the production of radium, which has been suggested by some, is entirely excluded. He also mentions experiments made to determine whether radium is formed directly from uranium. These showed no evidence of this change after a period of seven months and confirm the results of similar experiments by Soddy, so that it is probable, as suggested by Rutherford, that one or more intermediate changes exist between the uranium atom and the radium atom. Attention is called to the persistent appearance of lead as a constituent of uranium-radium minerals as an indication that this metal may be one of the final products of the disintegration of uranium.—*Phil. Mag.* (6), ix, 599. H. L. W.

4. *Marceli Nencki, Opera Omnia—Gesammelte Arbeiten von* Prof. M. Nencki—Erster Band, 1869-1885; Zweiter Band, 1886-1901. Large 8vo, pp. xliii + 840, and xiii + 893. Braunschweig, 1905. (Friedrich Vieweg und Sohn.)—These two sumptuous volumes, edited by N. Sieber and J. Zaleski, contain a fine portrait of Nencki as a frontispiece, a sketch of his life, a complete collection of his scientific writings, as well as numerous articles by pupils working under his direction. The work is an important and useful one, because Nencki's publications are scattered through many different journals, and because of the scientific value of his researches. Nencki's work covers a wide field, and the articles have been systematically indexed by the editors. There are many important investigations in pure chemistry—it is said that he took pride in having made over one thousand elementary analyses—but it is well known that his most important work was in the lines of physiological and medical chemistry, and

the book will be particularly useful to those interested in these branches of science. H. L. W.

5. *Manual of Chemical Analysis as Applied to the Assay of Fuels, Ores, Metals, Alloys, Salts, and other Mineral Products;* by EUGÈNE PROST; translated by J. CRUICKSHANK SMITH. 8vo, pp. 300. London, Maclaren & Sons; New York, D. Van Nostrand Company, 1904.—The object and scope of this work are set forth in the title. It should serve as a useful book of reference for analytical chemists engaged in technical work, for many of the methods of analysis are well selected and carefully described. A good feature of the book is the introduction of typical analyses of many commercial products, which give the chemist an idea of the ingredients to be looked for as well as the extent to which they are liable to occur. The book may be criticized on account of failing to include certain useful and reliable methods. For instance, Drown's method for the determination of silicon in pig iron is not given, while tared paper filters are recommended for weighing precipitates in cases where the Gooch crucible would give far better service, and other antiquated features from an American point of view are to be noticed. Not all of the methods are described in such a way that they would give a satisfactory degree of accuracy when implicitly followed, and in some cases the directions are decidedly lacking in completeness, or the methods are faulty in principle. The book is, therefore, not a perfect one, although it contains much that is useful. It seems unfortunate that the translator should have employed incorrect chemical nomenclature in some cases; for instance, chloride of soda for sodium chloride. H. L. W.

6. *Radiation Pressure.*—Professor POYNTING discusses simple methods of showing the pressure of light, and applies his theory of the stream of momentum. Theory and experiment seem to indicate that when a source is sending out waves it is pouring out with them forward momentum as well as energy, the momentum being manifested in the reaction, the back pressure against the source, and in the forward pressure when the waves reach an opposing surface. The wave train may be regarded as a stream of momentum traveling through space. Radiation pressure has not succeeded in explaining the repulsion of comet's tails. Professor Poynting suggests the following explanation of Saturn's rings: Let us imagine that a small sun while still radiating much energy on its own account has captured and attached to itself as satellite a cometary cloud of dust. Then, if the cloud consists of particles of different sizes, while all will tend to draw into the primary, the larger particles will draw in more slowly. But if the larger particles are of different sizes among themselves, they will have different periods of revolution, and will gradually form a ring all round the planet on the outside. Meanwhile the finer particles will drift in, and again differences in size will correspond to difference in period and they too will spread all around, forming an inner fringe to the ring. If there are several grades

of dust with gaps in the scale of size, the different grades will form different rings in time.—*Phil. Mag.*, April, 1905. J. T.

7. *Spontaneous Ionization of Air in closed Vessels and its Causes.*—The conductivity of air and other gases is generally attributed to the presence of free ions, and as these free ions are continually recombining there is some agency which is splitting up the combinations. Ionization in which no artificial ionization agent is employed has been called spontaneous ionization. The hypothesis that the ionization is due to a penetrating radiation constantly passing through the atmosphere has been advanced and is largely adopted. Alexander Wood of Emmanuel College, Cambridge, believes from a careful inspection of indirect evidence that all matter is radio-active and that the disintegration processes going on in radium and the other radio-active elements are going on also, though to a much smaller extent, in all matter. —*Phil. Mag.*, April, 1905. J. T.

8. *Radio-activity and Chemical Change.* — N. R. Campbell finds that there is no evidence that chemical change is accompanied by radio-activity; and that the spontaneous leak increase which has led some investigators to suggest such a connection is due to the heating of the walls of the vessels.—*Phil. Mag.*, April, 1905. J. T.

9. *Helium Tubes as Indicators of Electric Waves.* — Geissler tubes filled with argon, neon and other gases have been used by various investigators of electric waves along wires. Ernst Dorn finds that tubes filled with helium, $\cdot 5\text{-}5^{\mathrm{mm}}$ pressure are very sensitive and do not require a dark room.—*Ann. der Phys.*, No. 4, 1905, pp. 784–788. J. T.

10. *The Specific Heat of Water and the Mechanical Equivalent of Heat.*—The leading article in the Annalen der Physik, No. 4, 1905, by C. Dieterici, is a careful consideration of this subject, and is remarkable for the use the author makes of vessels of amorphous quartz. The method adopted in determining the specific heat of water was to enclose a definite quantity in a quartz cylinder and after raising it to a measured temperature to suddenly immerse it in a Bunsen ice calorimeter. The value $419{\cdot}25 \times 10^6 \frac{\text{erg.}}{\text{cal.}}$ was obtained for the mechanical equivalent of heat.—*Ann. der Phys.*, No. 4, 1905, pp. 593–621. J. T.

11. *Photograph of the Solar Corona without a Total Eclipse.* —In the opinion of M. J. Janssen, M. A. Hansky has succeeded in photographing the corona of the uneclipsed sun. The results were obtained at the observatory of Mt. Blanc by the use of the selective absorption of different screens. The direct rays of the sun were shut off by a disc. The negatives show distinct halos around the disc of the sun. Photographs illustrate the paper.—*Comptes Rendus*, No. 12, 1905, pp. 768–778. J. T.

12. *Kristallinische Flüssigkeiten und Flüssige Kristalle;* von Dr. Rudolf Schenck. 159 pp., 8vo, with 86 figures in the text. —The highly important work of Lehmann on "Flüssige Kristalle" was published a year ago and presented a large array of interest-

ing and novel phenomena in regard to liquids, which under certain conditions exhibit the phenomena of double-refraction. The present volume is a further contribution to the same remarkable subject in which the observations of the author and his associates, particularly as the physico-chemical properties of the liquids, are given in detail. These phenomena, in general, are exhibited through a definite interval of temperature included between the point of fusion and the "Klarungs-punkt," or that at which the transition to the transparent isotropic fluid takes place. The chapter discussing in detail the properties of these two points, their relation to the density, their dependence upon the pressure, upon the presence of foreign constituents and other related points is of great interest. Another chapter not less important, treats of the viscosity and other properties of the "crystalline" and isotropic fluids. The author wisely makes free use of the work of Lehmann and by this means is enabled, in a limited space, to present an excellent summary of the entire subject.

13. *"N" Rays: A Collection of Papers communicated to the French Academy of Sciences with additional Notes and Instructions for the Construction of Phosphorescent Screens;* by R. BLONDLOT; translated by J. GARCIN. Pp. xii, 83; with phosphorescent screen (frontispiece) and other illustrations. London and New York, 1905 (Longmans, Green & Co.).—The subject of the "N"-rays* is one that has excited much attention, although there have been some to raise the question as to the objective reality of the phenomena described. In any case, however, it is a matter of great interest to have the original papers of Professor Blondlot translated and brought together in a single volume; this work has been well done by M. Garcin. Fifteen papers are included, all reprinted as they were originally published in the Comptes Rendus of the French Academy. A number of plates are introduced which show the phenomena described, and the frontispiece consists of a phosphorescent screen of calcium sulphide for use in the observation of the "N"-rays, and prepared in accordance with the methods described in the closing pages of the volume.

14. *Das elektrische Bogenlicht, seine Entwickelung und seine physikalischen Grundlagen;* von W. B. VON CZUDNOCHOWSKI, Zweite Lieferung, pp. 99–194; dritte Lieferung, pp. 195–290. Leipzig, 1905 (S. Hirzel).—The second and third parts of this exhaustive work on the electric arc-light, announced in an earlier number of this Journal, have recently been issued. These are largely devoted to a historical discussion of the development of the arc-light from the time of Volta and Davy down to 1900. The subject has now reached so definite and relatively simple a stage that it is interesting to recall the many and varied attempts to solve the problems which had to be made before success was

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* Named in allusion to the city (Nancy) at the university in which the author is professor.

finally attained. The prominent forms of regulators, devised from time to time, are described fully and in historical order. The various special problems which have arisen, as the division of the electric light, the application of the light for signals at sea, the relation of light intensity to distance of visibility, and so on, are also treated in detail. The three parts now issued complete about one-half of the work as planned.

15. *The new Knowledge: A popular Account of the new Physics and the new Chemistry in their Relation to the new Theory of Matter;* by ROBERT KENNEDY DUNCAN. 263 pp., 8vo. New York, 1905 (A. S. Barnes & Co.).—There is no reason why, at the present day, the intelligent laymen should not acquire a reasonably good knowledge of the progress that is being made in the different branches of science, for books are not wanting which put before him the facts in a form requiring a minimum of preliminary training. The volume at hand is one having this object, but its scope is broader than usual, and the nature of matter, as now understood, and the light thrown upon the subject by the phenomena of electricity and radio-activity are presented with much system and clearness, and with a style to attract the reader. The closing chapters reach out beyond the earth to some of the problems of the stellar universe.

16. *Percentage Tables for Elementary Analysis;* by LEO F. GUTTMANN, Ph.D. 43 pp. 8vo. New York and London, 1904 (Whittaker & Co.).—These tables, reproduced here from the German edition, will be found most useful by the practical chemist, as they give him at once with all necessary accuracy (to four decimal places), from the amount of carbon dioxide and water yielded on combustion by the substance under examination, the percentage of carbon and hydrogen which it contains. A proportional table opens the volume and one for the reduction of volumes of nitrogen to grams is added at the end.

## II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey,* CHARLES D. WALCOTT, Director.—The following publications have been recently received; notices of some of them are deferred to a later number.

GEOLOGIC FOLIOS. No. 117. Casselton-Fargo Folio, North Dakota–Minnesota; by C. M. HALL and D. E. WILLARD.

No. 118. Greeneville Folio, Tennessee–North Carolina; by ARTHUR KEITH.

No. 119. Fayetteville Folio, Arkansas–Missouri; by G. I. ADAMS and E. O. ULRICH.

PROFESSIONAL PAPERS. No. 32. Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains; by N. H. DARTON. 433 pp. 4to, 72 plates, 18 figures.

No. 39. Forest Conditions in the Gila River Forest Reserve, New Mexico; by THEODORE F. RIXON. 89 pp. with folded map and diagram.

**Bulletins.** No. 238. Economic Geology of the Iola Quadrangle, Kansas; by G. I. **Adams**, E. **Haworth** and W. R. **Crane**. 80 pp., with 11 plates, 13 figures.—The Iola Quadrangle embraces an area of 944 sq. miles in the southeastern portion of Kansas. It lies in the prairie plains region characteristic of the eastern portion of the state, and is of especial interest because of its extensive oil and gas resources. The geological structure and relations of the oil and gas are in general similar to those prevailing over the entire Kansas-Indian Territory field, and hence the facts brought out in this bulletin, which is issued in advance of the Iola folio now in preparation, will be found useful by those interested in other portions of the field.

Briefly stated, the rocks exposed by outcrops and revealed by the drillings belong to the Pennsylvanian series of the Carboniferous. This series, known as the Coal Measures, contains beds of workable coal chiefly in the lower portions ; the Boone limestone of the Mississippian series lies below the Coal Measures. The oil and gas of the region are largely confined to the Cherokee shales, which here form the lowest section of the Coal Measures and have a thickness of some 450 feet. The oil and gas reservoirs are associated with beds of sandstone, of varying extent and thickness, and sometimes of very local extent. Many facts of an economic importance are brought out in the bulletin, particularly with reference to the gas wells. This region also affords considerable quantities of Portland cement and there are important brickmaking plants.

No. 242. Geology of the Hudson Valley between the Hoosic and the Kinderhook ; by T. **Nelson Dale**. 63 pp., 3 plates including a geological map, 17 figures.

No. 246. Zinc and Lead Deposits of Northwestern Illinois ; by H. **Foster Bain**. 56 pp., 5 plates, 3 figures.—The region covered by this paper lies in the extreme northwestern portion of the state, including a part of Jo Daviess county. Another region, also yielding zinc and lead minerals, is found in the southern portion of the state (in Hardin, Pope and Saline counties) and forms part of the Kentucky-Illinois fluorspar, lead and zinc field. The former region, here described, has been known to yield lead since 1700 and mining operations have been carried forward for upwards of one hundred years. Much has been written by different authors as to the mineralogical nature of the deposits, the method of their occurrence and their origin ; the present paper gives a convenient and concise summary of the facts as now known, upon what the writer's observations have served to throw additional light.

No. 249. Limestones of Southwestern Pennsylvania ; by **Frederick** G. **Clapp**. 52 pp., 7 plates.—The subject developed in this paper is the character and distribution of limestones suitable for Portland cement, or for other economic uses. Sixteen layers of limestone are recognized and named, varying in thickness from 60 to 6 feet ; the occurrences are described and the prospective value of each estimated.

No. 250. The Petroleum Fields of the Pacific Coast of Alaska with an account of the Bering River Coal Deposits; by George C. Martin. 64 pp., 7 plates, 3 figures.—The observations made thus far are preliminary only, but they serve to show that at several points on the Alaska coast, conspicuously near Controller Bay, about 100 miles west of Mt. St. Elias, petroleum occurs in some quantity, and the region may prove to be an important source in the future; explorations thus far made are, however, inconclusive. The best coal thus far found on the Pacific coast is that of Bering river which flows into Controller Bay. Petroleum fields have also been somewhat developed on the western shore of Cook Inlet and on Cold Bay opposite Kodiak Island.

No. 252. Preliminary Report on the Geology and Water Resources of Central Oregon; by Israel C. Russell. 138 pp. 24 plates, 4 figures.—This bulletin gives, as the result of a rapid reconnoisance, an interesting and well illustrated account of a little known region in central and eastern Oregon. It includes the extreme northern part of the Great Basin, which has no external outflow, and also a part of the drainage area of the Deschutes and Crooked rivers. Much of it is an arid region, conspicuously the "Great Sandy Desert," which has a length of 150 and a width of 30 to 50 miles. Of the hills or mountains of the region, much the greater number owe their origin to volcanic eruptions, the cones being particularly abundant to the west in the neighborhood of the Cascade Mountains. The volcanic rocks are mainly rhyolites, andesites and basalts, the last named being in general the latest, though certain andesites and andesitic tuffs are the youngest of all the lava outflows. In the west-central part of the state an extensive shell of pumice, similar to that about Crater lake described by Diller, forms a thick mantle over the surface. The sedimentary formations consist of soft, or partially consolidated beds, of Tertiary age. Interesting observations, with excellent views, are given of the present glaciers, particularly on the three peaks of the Cascade Mountains known as the Three Sisters. In regard to the extent of former glaciation the writer states "that during a former period, which can be safely correlated with the Glacial epoch, great snow fields covered the summit portion of the Cascade Mountains throughout their entire extent across Oregon, and from this névé region large alpine glaciers flowed eastward down the mountains. Glaciers also occurred on the west side of the range, but no new facts concerning them can be presented at this time. The conditions were of the same general character as existed on the Cascade Mountains in Washington, but the eastward-flowing ice streams were seemingly less extensive. An instructive suggestion in reference to the glaciers on the east side of the Cascade Mountains in Oregon is furnished by the fact that in the southern portion of the state, in the vicinity of Mounts Scott and Mazama, the eastward-flowing glaciers are larger and of greater length than farther north in the vicinity of the Three Sisters peaks and

Mount Jefferson. If this conclusion is sustained by future studies, an explanation of it will perhaps be suggested by comparing the present climatic conditions of the two regions."

No. 258. The Origin of certain Place Names in the United States (second edition); by Henry Gannett. 334 pp. This paper is a second edition of that published as Bulletin No. 197; it contains a large amount of useful geographical information.

No. 259. Report on Progress of Investigations of Mineral Resources of Alaska in 1904 ; by Alfred H. Brooks and others. 196 pp., 3 plates, 10 figures.—This bulletin gives an account, by the different geologists at work, of the information gathered during the last season in regard to the various mineral deposits of Alaska. Nine parties were in the field, five of them engaged in geologic work, two in topographic surveys, one was a combined geologic and topographic party and one studied the methods and costs of placer mining. The larger part of the bulletin is devoted to the gold placers, but an account is also given of the Treadwell ore deposits on Douglas Island, as, too, of the recent development of tin deposits in Alaska. Further, the coal and petroleum resources of Alaska are discussed in detail (see also Bulletin No. 250).

No. 261. Preliminary Report on the Operations of the Coal-testing Plant of the U. S. Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904 ; E. W. Parker, J. A. Holmes, M. R. Campbell, Committee in charge. 192 pp.

No. 264. Record of Deep Well Drilling for 1904 ; by M. L. Fuller, E. F. Lines and A. C. Veatch. 106 pp.—The work of the Survey, in regard to the accummulation of geological and physical data of deep wells, although only recently inaugurated, is now so well organized that a very large amount of useful material is promptly brought together and given to the public. The paper now issued is the first of the series planned and presents the material received during the first six months of the work. A tabular summary is given for 358 wells and detailed records are added of a number of selected cases yielding information of importance.

Water-Supply Papers. No. 109. Hydrography of the Susquehanna Drainage Basin ; J. C. Hoyt and R. H. Anderson. 210 pp.

No. 111. Underground Waters of Washington; Henry Landes. 85 pp.

No. 113. Disposal of Strawboard and Oil-well Wastes ; R. L. Sackett and I. Bowman. 52 pp.

No. 114. Underground Waters of the Eastern United States ; Myron L. Fuller. 285 pp.

No. 115. River Surveys and Profiles made during 1903 ; arranged by W. C. Hall and J. C. Hoyt. 115 pp.

No. 116. Water Problems of Santa Barbara, California; J. B. Lippincott. 99 pp.

No. 117. Lignite of North Dakota and its Relation to Irrigation ; by F. A. Wilder. 59 pp.

No. 120. Bibliographic Review and Index of Papers relating to Underground Waters, U. S. Geol. Survey, 1879–1904; by Myron F. Fuller. 128 pp.

No. 121. Preliminary Report on the Pollution of Lake Champlain; by M. O. Leighton. 119 pp.

No. 122. Relation of the Law to Underground Waters; by D. W. Johnson. 55 pp.

2. *Contributions to Devonian Paleontology;* by H. S. Williams and E. M. Kindle. Bull. U. S. Geol. Surv., No. 244, 1905, pp. 1-144.—The purpose of this Bulletin is to present the evidence regarding "the nature of the changes in sedimentation, in fossils and in sequence of faunas southward along the Devonian formations in the southern Appalachians." The Devonic sections of the Falls of Ohio region, of southwestern and central western Virginia, east-central Kentucky, and West Virginia, are analyzed and compared with one another. Then the upper Devonic sections in central and northern Pennsylvania are compared with those of New York. This Bulletin will have lasting value because of the many sections it describes in detail and the many faunules listed.

The fossils from the Helderbergian and Oriskanian horizons in Virginia and West Virginia led Professor Williams to conclude "that the subdivisions of the Rensselaeria fauna [Helderbergian and Oriskanian], which in the northern Appalachian region have determined the division of the strata into numerous separate formations, are not universal. Future investigations probably will show that the composition of the local faunules is determined rather by environmental conditions recorded by the differing characters of the sediment than by actual epochs in their history" (p. 49). The present writer will state that he has collected at nearly all of the southern localities described in this Bulletin and at many others, and finds no great difficulties in correlating any one of the southern faunules with the minor horizons of the New York Helderbergian, and this irrespective of the nature of the sediments. In regard to a complete Oriskanian development New York is a poor standard, whereas the Cumberland region is far better. Combining the New York and Maryland sections, the writer is able to state that the New Scotland, Coeymans, and Manlius occur at Big Stone Gap, Va. The "faunule of zone 2 of section 1376 A" and 1376 B2, on p. 28, are unmistakably New Scotland and not "Oriskany." On the "coarse sandstone" rests the Chattanooga Black shale. No Oriskany was seen about Big Stone Gap. To the northeast, near Bluefield, W. Va., there may be a little Lower Oriskany, but in the region of Covington, Va., there probably is not less than 35 feet of typical or Upper Oriskany. At the Low Moor Iron Co. mines, the writer collected *Spirifer arenosus*, *Meristella lata*, *Rensselaeria* sp. undet., *Eatonia singularis*, *Leptæna rhomboidalis*, and *Diaphorostoma ventricosa*.

There is considerable evidence of an erosion interval in the southern Appalachians before the Black shale invasion, for in the region of Covington, Va., this may be seen resting at times on the Oriskany or the Becraft limestone, which is very well developed here. About Cumberland, Md., the maximum thickness for the Oriskany is about 300 feet. In sections only a few miles apart the thickness will vary from this down to 50 feet, and these thinner sections always carry a Lower Oriskany fauna, indicating a land interval here subsequent to the Upper Oriskany and before the Marcellus. The writer knows of no typical Onondaga (Corniferous) faunas south of northeastern Pennsylvania, and the faunules listed in this Bulletin, as, for instance, 1382 B3 and 1383 A2 and 3, are decidedly more Marcellus than Onondaga. Owing to the irregular pre-Marcellus erosion producing an uneven topography, it follows that the invading base of the Black shale will be different in different places. It is the writer's working hypothesis that owing to the Onondaga erosion interval and the low-lying fold which delimited the western boundary of the Cumberland Basin, the base in different localities may be anywhere between basal Marcellus and the higher Devonic. The Helderbergian and Oriskanian deposits are in full development in Maryland, but thin out rapidly southward, and none attain very far south of the Tennessee-Virginia boundary line. The Manlius, Coeymans, and New Scotland are typically present as far south as Hancock county, Tenn. The Becraft is in full force about Covington, Va., but is gone before Big Stone Gap is reached. The Lower Oriskany is present in the Hicksville, Va., faunule 1379 A1, but no Upper Oriskany. In other words, the waters of the Cumberland Basin extend from Hancock county, Tenn., north into Pennsylvania, throughout Manlius, Coeymans, and New Scotland time. With the Becraft there begins an emergence at the south, slowly dissipating the sea to the north, so that Oriskany sediments do not appear much south of Covington, Va. In Maryland the sea is continuous from the early Siluric to the end of Oriskany time, when emergence also sets in here and affects the Appalachian trough as far north as northeastern Pennsylvania.

Along the eastern side of the Cincinnati axis the invading Black Shale is never older than the Genesee. Here, again, the base is variable, but apparently is always within the time of the Genesee. This variability is due not only to the erosion unconformities pointed out by Dr. Kindle, but also to the transgression of the Genesee sea upon the Cincinnati axis.

Several species of the *Buchiola speciosa* (= *B. retrostriata*) fauna have their first appearance in the Marcellus and are apt to recur throughout the higher Devonic whenever the Black shale conditions prevail. Most of its species have a long range, as may be seen from the table on pp. 51, 52, of this Bulletin. Here 25 species are positively identified. If *Anoplotheca acutiplicata* occurs in this fauna in Virginia (can it be a Vitulina ?) no particular time value can be assigned to it against the 24 other associated forms, none of which are known to appear before Marcellus time. It therefore seems to the writer unwarranted to conclude, as does Professor Williams, that "the black shales range from as low as the Onondaga." Admitting this identification, then, not only does the form in question persist into Marcellus or later time, but there are, as is well known to Professor Williams, many other Onondaga species persisting into Hamilton time in other faunules than those listed in this Bulletin (*Chonetes mucronatus*, *Pentagonia unisulcata*, *Parazyga hirsuta*, *Rhipidomella vanuxemi*, *Spirifer acuminata*, etc.). With these facts in view, it does not follow that the Black Shale ranges "from as low as the Onondaga." The *Buchiola retrostriata* fauna is a puzzle to stratigraphers other than Professor Williams. It comes to America as a migrant along an unknown path (there are three possibilities), appearing in part first in the Marcellus, recurring always with the Black shale conditions, and evidently is finally made up of other later migrants and stragglers from the American Hamilton faunas.

The sections and faunal lists of "Devonian sections in Central and Northern Pennsylvania" are given in great detail and have an especial value in connecting the type area of New York with the middle and southern Appalachians. For the first time, here is found a carefully collected sequence of Upper Devonic faunules; also the relation of the Catskill formation to the Chemung of Pennsylvania.

In conclusion, the writer will state that it is not shown that stratigraphers can not rely upon the fossil assemblages, as presented in these faunules, for definite correlation of formations over wide areas and especially within faunal provinces. The top and bottom of the correlated formations may not be everywhere exactly contemporaneous, yet for practical purposes they are fairly exact. It is true that the faunules are ever changing and that they are controlled to some extent by the character of the sediments (in some cases very largely so, and this is particularly true of the Black shale condition), but in nearly every faunule this constant change preserves a something by which its time position can be recognized. At times this something is the presence of a certain species, the dominance of a certain few species, the assemblage or absence of a certain species, controlled by the stratigraphic position of the faunule. It is known that many of the New York Hamilton Bryozoa and Ostracoda occur at the top of the Onondaga in the Falls of Ohio region, and Dr. Clarke has suggested that the top of the Onondaga limestone in New York probably is a tangential horizon, one end of which lies in Onondaga, the other in Marcellus time. Features further complicating these Devonic faunas, and to which but very few paleontologists have given attention, are the sources of the faunas, the paths of migration, and the barriers or low anticlines that originated at different times in the American Paleozoic epicontinental seas, resulting from Appalachian and Arkansas-Oklahoma movements.

Some conclusions resulting from the work recorded in this Bulletin are set forth by Professor Williams in another paper entitled "Bearing of some new paleontologic facts on nomenclature and classification of sedimentary formations" (Geol. Soc. Amer., 1905). His conclusions are at variance with the experience of other paleontologists, a fact clearly brought out in a recent discussion by the paleontologists of the U. S. Geological Survey (Stanton, Dall, Ulrich, and White) and summarized in Science, April 14, 1905 (pp. 583–585). CHARLES SCHUCHERT.

3. *Structure of some Primitive Cephalopods;* by R. RUEDEMANN. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 296–341, pls. 6–13.—This very important and highly instructive paper treats in the main of the structure and development of *Endoceras brainerdi* of the lowest Ordovicic of the Lake Champlain region. It is shown that this primitive cephalopod begins with a protoconch followed by a long, gradually tapering, rather large and non-septate cone, as in Nanno and Vaginoceras. After attaining a length of about 70$^{mm}$, a slight constriction of the cone takes place and at this point it may be said that the wall of the cone divides, the inner division (or conchiolinous portion) to continue as the wall of the siphuncle (a continuation of the original cone cavity), while between it and the outer calcareous wall is developed the camerated space, or phragmocone. Within the siphuncle, after a few of the cameræ have been developed, there then appear other cones, the endocones, which communicate with one another by means of a central canal, or "endosiphuncular canal." The wall of the siphuncle rests against the recumbent edges of the cameræ walls until within a few inches of the terminal growth, where the cameræ (or "septal necks") form the lining to the large siphuncle opening directly into the living chamber. There are further siphuncular complicating structures about the endosiphuncular canal too complicated to be given here in a few words. However, it should be added that these developments led the author to a comparison of these structures with the Belemnites, and he concludes that the "endosiphocoleon" of endoceroids and the proöstracum in the Belemnites are "formed in identical places," i. e., "within a mantle flap or fold situated at the posterior end of the animal."

The author then discusses various early endoceran genera and concludes that the genera Cameroceras (syn. Endoceras) and Vaginoceras have earlier generic types for which he proposes Proterocameroceras and Proterovaginoceras. The latter is considered to contain the radical stock for these primitive forms. As Piloceras is closely related to these genera, the author also studied the development of this genus in *P. explanator*. From a study of this form he concludes that there is also here an earlier type with an external primitive cone, as in Proterocameroceras. To this very interesting but as yet undiscovered form, he gives the generic name Proteropiloceras, which of course no one is obliged to accept, under the rules of nomenclature. *Piloceras* *newton-winchelli* Clarke is shown to be an Orthocerocone retaining Endocerocone structures, and is made the genotype of a new genus. This animal, therefore, bears the long and barbaric name *Clarkoceras newton-winchelli*. C. S.

4. *Notes on the Siluric or Ontaric section of Eastern New York*; by C. A. Hartnagel. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 342–358.—This paper gives a clear exposition of the late Siluric deposits of southeastern New York and their correlation with the same horizons of the western part of the state. It is established that these deposits were laid down in two contemporaneous seas, a western or Mississippian sea and an eastern basin, the Cumberland. At times some of the species are common to the two waters, but as a rule each has its distinct fauna.

The Shawangunk, heretofore accepted as basal Siluric, is shown to be probably the basal or invading Salina sandstone in the Cumberland Basin. C. S.

5. *The Trilobites of the Chazy Limestone*; by Percy E. Raymond. Ann. Carnegie Mus., III, 1905, pp. 328–386, pls. 10–14.—During the past five summers, Mr. Raymond has been studying the Chazy in the field, and here are presented his first laboratory results. All the known Chazy trilobites are described, 35 in number, of which 18 are new to the Chazy formation. A new subgenus *Glaphurus* is proposed. The genus *Ceraurus* is restudied, and the species referred to four divisions—*Ceraurus*, *Sphærocorphe*, *Pseudosphærexochus*, and *Nieszkowskia*. This paper should be studied in connection with one by the same author in the May number of this Journal.

The author brings out the interesting fact that the four orders of trilobites into which the class is divided are present in this old Ordovicic fauna; further, that the Chazy trilobites are closely related to those of the Trenton, and that three species are common to the two formations. With the Beekmantown below, there is far less agreement. C. S.

6. *Contributions to the Fauna of the Chazy Limestone on Valcour Island, Lake Champlain*; by George H. Hudson. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 270–295, pls. 1–5.—This is the first paleontologic publication of Professor Hudson, and describes 1 new cystoid, 3 crinoids, 2 brachiopods, 2 pelecypods, 6 gastropods, and 1 trilobite. C. S.

7. *Ueber Pteraspis dunensis* F. Roem. sp.; by F. Drevermann, in Marburg. Zeitschr. Deut. geol. Gesellsch., 56, 1904, pp. 275–289, pls. 19–21.—A very important paper on this Lower Devonic fish, based on many specimens recently discovered at Hamm, on the river Sieg, by Dr. Drevermann. C. S.

8. *Notice of a new Crinoid and a new Mollusk from the Portage rocks of New York*; by R. P. Whitfield. Bull. Amer. Mus. Nat. Hist., 21, 1905, pp. 17–20, pls. 1–4.—The crinoid is *Maragnicrinus portlandicus*, genus and species new. *Onychocardium portlandicum* is the new genus and species of bivalve. Remarks are also made on *Cyathocrinus ornatissimus*, which the author refers to *Cosmocrinus*. C. S.

9. *Fossils of the Bahama Islands, with a list of the non-marine mollusks;* by W. H. **Dall.** (The Bahama Islands, edited by G. B. Shattuck. See 12, below.) Geogr. Soc. Baltimore, 1905, pp. 23–47, pls. 11–13. In this paper are described a number of new species. The list of Bahama land shells, recent and fossil, has 171 species and varieties. Of marine fossil mollusks there are 51 species. The fauna of the "salt pans" has 12 species, of which 6 are peculiar to these lagoons. C. S.

10. *On the Relations of the Land and Fresh-water Mollusk-fauna of Alaska and Eastern Siberia;* by W. H. **Dall.** Popular Sci. Monthly, Feb., 1905, pp. 362–366.

11. *Geological Survey of Ohio,* Edward Orton, Jr., State Geologist. Fourth series, Bulletin No. 3. *The Manufacture of Hydraulic Cements;* by A. V. **Bleininger.** Pp. xiv, 391. Columbus, Ohio, 1904.—The author has brought together in this volume a large amount of information relating to the different materials suitable for Portland cement and the methods of their manufacture. Much of the matter here given has not hitherto been accessible in English books. Attention is given particularly to the chemical side of the subject and the writer contributes also the results of his own researches.

12. *The Bahama Islands.* 630 pp. 93 plates. 7 figures. New York, 1905. (The Macmillan Company.)—This elaborate volume on The Bahama Islands is the product of an expedition of the Geographical Society of Baltimore, led in 1903 by Prof. Geo. B. Shattuck. Much assistance was received from several governmental Bureaus in Washington as well as from Johns Hopkins University in the way of instrumental and other outfit for the expedition. The volume treats the islands in all their aspects, scientific, hygienic, historic, economic; no less than fifteen authors contribute to its pages. The presence of water-filled caves to a depth of 300 feet and the discovery of recent bedded deposits with abundant marine fossils at heights up to 10 or 15 feet above sea-level in certain islands are taken to indicate former higher and lower stands of the land. Marine erosion, as well as preponderating submergence, is held responsible for the great diminution of a much larger former land area. The variety of soils, as indicated on soil maps of several islands, is greater than might be expected on a foundation of limestone alone. Pineapples are the most important agricultural product; in some plantations they are grown in the little pockets weathered in the limestone surface. The history of the islands, with special regard to slavery, is given in detail. It was reported after the Baltimore conflagration that the Geographical Society was seriously affected by that disaster; but the issue of this handsome volume leads us to hope that the Society has only been temporarily affected, and that it will soon regain the vigor with which its career was begun. W. M. D.

13. *La Montagne Pelée et ses Éruptions;* by A. **Lacroix.** 4to. Paris, 1904 (Masson et Cie).—In this imposing and beau-

tifully illustrated volume, which is published by the Académie des Sciences of Paris, Prof. Lacroix, the chief of the French Scientific Commission sent to investigate the phenomena of Pelée and the general conditions attending the destruction of Saint-Pierre, presents his final report on his observations. This is the most extended study that has yet been made of the cataclysm of May, 1902, and of the volcanic phenomena of the island that followed upon this remarkable outburst. Much of what the volume contains has already appeared in advance papers published in the *Comptes Rendus*, and the conclusions advanced have also in large part been anticipated, both by the author himself and by the foreign investigators who preceded Lacroix in their investigations, but for all that the work stands as one of the finest contributions to vulcanology which geological literature contains, and it is to be hoped will be made a measure for future exploratory work of the same kind that may be initiated. On the main points connected with the now historic cataclysm, Prof. Lacroix holds generally to the views that have been advanced by the American investigators. The destroying blast of May 8 was an explosion of steam, with other gases, directed initially downward from the ancient crateral spot of the volcano, the Étang Sec, and has in kind been repeated a number of times since (the *nuées ardentes*), as on May 20, June 6, July 9, Aug. 30 (destruction of Morne Rouge) and other periods. Heated to a very high temperature, which may have reached 1500° to 2000° or more, densely charged with volcanic debris that it carried in its train, and descending with a velocity which at its point of impact with the unfortunate city is estimated to have been not less than 400 to 450 feet per second, it is not difficult to comprehend why the destruction should have been so absolute and far-reaching. In attributing the descent of the destroying "black cloud" to an initial explosive discharge whose direction was downward, and not to the attractive force of gravity, Lacroix stands in accord with virtually all the American investigators, and opposed to Drs. Flett and Tempest Anderson, representing the Commission of the Royal Society of London. The author is inclined to the belief that Saint-Pierre was annihilated in the space of a single minute, or perhaps even within a fraction of this time. As regards the construction of the remarkable Peléan excrescence which has been at various times described as "spine," "tower," "obelisk," and "needle," and which at its greatest development rose above its supporting dome by upwards of 1000 feet, Lacroix holds to his original views, somewhat modified in its details, that it represented a rapidly solidifying highly viscous (andesitic) lava, whose upward movement was conditioned by almost instantaneous solidification, and the impossibility under such conditions of taking the downward course of ordinary lava-streams. However much one may feel disposed to differ from this conclusion, the observations which have led to it are carefully stated, and form not the least important part of the work. A large part of the volume is taken up with petrographical research, the author's own particular field of inquiry, which gives an interesting and most important vista into the theory of the formation of quartzitic rocks and the occurrence of free quartz in volcanic magmas.

ANGELO HEILPRIN.

Philadelphia, April 22, 1905.

14. *Recherches géologiques et pétrographiques sur l'Oural du Nord;* par L. DUPARC et F. PEARCE. Mem. Soc. Phys. d'Hist. Nat. Genève, vol. 34, fas. 5, pp. 383–602. Pls. and map. 1905.—The first portion of this work was published in 1902 (ibidem, pp. 57–218) and gave a general description of the portion of the region in the Urals which had been studied (Rastesskaya and Kizelowskaya-Datcha, Govern. Perm.) Different parts of the area were then taken up in detail, the geology described and the petrography of the igneous rock formations presented, accompanied by numerous analyses. In the second memoir these detailed descriptions are continued, studies of the crystalline schists are also given, and the work concludes with observations on the structural geology and summations of the results obtained.

The chief interest centers on the masses of igneous rocks which have been investigated in the field and laboratory; they are chiefly of basic ferro-magnesian types, gabbros, dunites and pyroxenites. Of the latter a special type is described consisting of a foliated pyroxene with a variable amount of olivine and magnetite; the texture is granitic; the magnetite, playing the same role as quartz in a granite, forms the cement to the other minerals. To this rock the name of *koswite* is given. To another type which contains a certain amount of feldspar rich in lime, but which differs chemically from the gabbros, the name of *tilaite* is given.

The work is enriched by many figures and half-tones in the text, and is not only an important and valuable contribution to our knowledge of the Urals, but contains much in addition that is of general interest to geologists and petrographers L. V. P.

15. *Einleitung in die chemische Krystallographie;* von P. GROTH. Pp. 80, 8vo. Leipzig, 1904 (Wilhelm Engelmann).—The author of this little volume has made so many important contributions to the subjects of Mineralogy and Crystallography, both separately and in their mutual relations, that it will not be a matter of surprise that the present volume, although brief in extent, is very helpful and suggestive in regard to the various topics it discusses. Its object, briefly stated, is to present the relations which exist between the properties of crystallized bodies and their chemical constitution as based upon a definite theory as to the structure of crystals. It is, moreover, introductory to an exhaustive work in preparation by the author, in which it is proposed to give a systematic and critical presentation of crystal forms and the physical properties of crystallized substances.

16. *Grundzüge der Krystallographie;* von Prof. C. M. VIOLA. Pp. x, 389, 8vo. Leipzig, 1904 (Wilhelm Engelmann).—This

volume is based upon the course of lectures which the author has delivered at the University in Rome. The subject, however, has been much expanded and developed, and now presents the Crystallography of the present day as viewed by the author, from a standpoint at once advanced and theoretical. The student whose interests lie in this, rather than in the strictly practical side of the subject, will find this work worthy of careful study.

## III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Ascent of Water in Trees;* by ALFRED J. EWART (abstract of a paper read before the Royal Society of London).—As the result of a series of experimental observations bearing upon this problem, the author has been led to the conclusions stated in brief below.

The flow of water through open vessels filled with sap takes place in accordance with Poiseuille's formula for the flow through rigid cylindrical tubes, divergences being due to the presence of irregular internal thickenings in the vessels, and to local constrictions or deviations from the circular outline.

Hence the velocity of flow is directly proportional to the pressure and to the square of the radius of the tube, inversely proportional to the length of the tube and to the viscosity of the liquid. A small number of large vessels, therefore, offer very much less resistance to flow than a large number of narrow ones having the same length, and the same total internal area of cross-section. Since viscosity is largely dependent upon temperature, the latter forms an important factor in regulating the flow, the viscosity and the resistance falling with a rise of temperature.

With an average rate of flow the total resistance due to the viscosity of the water flowing through the vessels is always less, and in climbing plants with large vessels is considerably less, than a head of water equal in height to the stem. The adult vessels of actively transpiring angiospermous trees always contain air-bubbles, and these introduce a resistance to flow which is inversely proportional to the radius of the tube, when the air-bubbles and the water-columns move together. When the air-bubbles are comparatively stationary, as in most vessels, the resistance is still further increased, and it becomes very great when the vessels are small and the air-bubbles numerous. In intact vessels containing air the rates of flow under similar pressures are proportional to a power of the radius lying between 1 and 2, the volume passing to a power of the radius lying between 2 and 4.

Estimations of the amount of flow, made from the rate of flow and the diameters and number of the vessels, showed that the actual flow takes place in the wood of dicotyledons almost entirely through the cavities of the vessels and hardly at all through the tracheides. In young stems saturated with water under pressure, a considerable flow takes place through the pith, but practically none in intact transpiring stems.

In a cut stem, apart from the blocking at the cut surfaces, a gradual diminution of conductivity occurs along its entire length after water has been passed through for some time. This appears, in part at least, to be due to the development of micro-organisms in the vessels, but may be aided by swelling, by lessened permeability, or by other changes in their walls.

The length of the vessels in the wood of the branches examined averages from 7 to 36 centimeters, the tracheides of the yew being from 0·2 to 0·5 of a centimeter in length. Since, however, the vessels appear mainly to end at the nodes where branches arise, it is possible that they may be much longer in the young wood on old bare trunks. The resistance to transverse flow through saturated wood is 800 to 45,000 times greater than to longitudinal flow, the resistance to filtration under pressure through a single partition wall being from 2 to 10 times greater than that to the flow through the entire length of a vessel filled with water in the wood of a crab apple.

The total resistance to flow in the erect stems of actively transpiring plants appears to correspond to a head of water of from 6 to 33 (shrubs and small trees), or from 5 to 7 (large trees) times the height of the plant. Hence in the tallest trees the total pressure required to maintain active transpiration may be equivalent to as much as 100 atmospheres.

No leaf could produce or maintain an osmotic suction of this intensity, and in the presence of large air-bubbles in the vessels the stress transmitted in them from the leaves could never be as great as an atmosphere. Vines* found, for instance, that the suction force of a transpiring branch was never greater than two-thirds of an atmosphere. The supposition that these forces might summate is entirely erroneous. On the contrary, the leaves at the base of a tree would pull water down from the upper vessels and leaves, instead of up from the roots, in the absence of any pumping action in the stem, and of any root-pressure.

If the air-bubbles in the vessels were exceedingly minute, they might be under a small positive pressure, while the water outside was under a maximal strain of five atmospheres. This would suffice to overcome the resistance offered during active transpiration by 30 to 80 feet of stem, hence the results obtained by Strasburger with dead stems. The maximal osmotic suction exercised by the leaves, as determined by comparing the osmotic pressures during active transpiration of the leaves at the top and bottom of an elm 18 meters high, appears to be from 2 to 3 atmospheres, and is usually less than this. At the same time the total resistance to flow in the trunk of this tree would be from 10 to 12 atmospheres.

It appears, therefore, that to maintain flow, a pumping action of some kind or other must be exercised in the wood, for which the presence of active living cells is essential. In support of this it has been shown that the production of wood in a slowly growing tree is greater than is necessitated by mechanical requirements. In other words, the production of new wood is largely determined by the length of time during which the wood-parenchyma can remain active.

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* Annals of Botany, 1896, vol. x, p. 438.

There is no known means by which these cells can directly pump water in a definite direction, although the existence of a power of absorbing and exuding water under pressure has been empirically determined to exist in the living wood of cut branches. It is suggested that the wood-parenchyma cells by the excretion and re-absorption of dissolved materials may bring into play surface-tension forces within the vessels of sufficient aggregate intensity to maintain a steady upward flow, and to keep the water of the Jamin's chains in the vessels in a mobile condition ready to flow to wherever suction is exercised upon it.* The rapid rates of diffusion required for such action do actually exist in the wood-parenchyma cells.

It appears that the terminal branches of trees at heights of from 22 to 44 feet above ground exhibit little or no power of bleeding in spring. Possibly in such trees the pumping action is only used or developed in the wood of the older stems, or is only exercised when transpiration is active, and when the water-columns in the vessels attain a definite size relatively to the wood-parenchyma cells. The importance of the Jamin's chain in the vessels is that it renders a staircase-pumping action possible, and enables the water to be maintained in the vessels in a labile condition, ready to flow to any point where moderate suction is exercised. This pumping action being diffused and probably regulated, need not produce any high pressure of exudation at the terminal branches of tall trees, which, in fact, appears always to be absent at high levels.—*Proc. Roy. Soc.*, lxxiv, 554.

2. *Problems of the Panama Canal;* by Brig.-Gen. HENRY L. ABBOT, U. S. Army, retired. 248 pp. New York, 1905 (The Macmillan Co.).—The position occupied for so many years by General Abbot in the Engineer Corps of the United States Army, and also his official connection with the new French company for the Panama Canal established in 1894, have made him particularly fitted to give an accurate and thorough presentation of the more important scientific problems involved in the present and future work on the Canal. The volume is a particularly timely one, and will be read with interest by the general public, as well as by those more immediately concerned. A brief historical introduction is given, followed by a chapter on the relative advantages of the two routes which have been discussed; to that of Panama unqualified approval is given. The bulk of the work, however, is devoted to the consideration of the peculiar physical conditions existing on the Isthmus, particularly those affecting

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* Surface-tension actions would be possible in the absence of air-bubbles wherever the wood-parenchyma cells contained oil or any other substance non-miscible with water, as they often do.

the prosecution of the work. These include chiefly the range of temperature during the different seasons of the year, and still more the amount and distribution of the rainfall; full details with numerous tables are given in both these directions. In connection with the latter subject, the hydraulic problems involved in the regulation of the Chagres River are discussed at length, and with the same thoroughness which characterizes the other parts of the work. The conclusion is reached that although the matter presents serious difficulties, they are not greater than those that have been met with elsewhere, and that "all that is required is a judicious plan of regulation based on well-established principles." With respect to the question that has arisen between a sea-level canal and one provided with a series of locks, the author speaks very emphatically in favor of the latter, on general grounds, as also because of the economy in time and money.

3. *A Primer of Forestry. Part II, Practical Forestry;* by GIFFORD PINCHOT, Forester. 88 pp., 12mo, Washington, 1905 (Bulletin No. 24, Part II, U. S. Dept. of Agriculture, Bureau of Forestry).—This little book, like its predecessor, presents the practical problems of forestry in most clear and attractive form. Indeed, brief as it is, the subject is put before the reader so conclusively that it seems difficult to understand why scientific methods are not everywhere employed in dealing with nature's effort to provide humanity with a lasting supply of useful woods, instead of the short-sighted policy so common in this country. The situation has improved materially since the Department of Forestry was organized, and greater progress through the enlightenment of the public is promised for the future.

4. *Field Operations of the Bureau of Soils, 1903.* Fifth Report. By MILTON WHITNEY, Chief, with accompanying papers by assistants in charge of field parties. 1310 pp., with 3 plates, 61 text figures and 78 maps in separate portfolio case. Washington, 1904 (U. S. Department of Agriculture, Bureau of Soils). —During the season of 1903, a total area of 26,543 square miles was surveyed and mapped by the various parties of the Bureau of Soils; this was divided over 61 separate areas, averaging 437 square miles each, in 37 states and territories. The detailed results of this extensive work are contained in these volumes recently given to the public.

5. *Mechanism;* by S. DUNKERLEY. 408 pp. New York and London, 1905 (Longmans, Green & Co.).—This book, while not designed to be a philosophical treatise on pure mechanism, is valuable for its many and modern applications of various machines. The first two chapters, including the introductory one, discuss the simpler types of machines and shop appliances, as well as combinations of belting and gearing. The more complete study of gearing and gear teeth is left to a later chapter. The geometrical properties of mechanism are next taken up with machines whose interest lies particularly in the paths traced by their parts. Steam engine indicators are conspicuous examples

described in illustration. One chapter embraces velocity-ratio diagrams and approximate solutions of link motions. Valve and steering gears, together with various link motions, are given here to exemplify. Another chapter is devoted to acceleration diagrams, which with the velocity-ratio diagrams, are most important in the study of the dynamics of machines. The subject of toothed circular and non-circular wheels is comprised in the last half of the book. The kinematic conditions which must be satisfied by profiles of teeth and methods mechanical and graphical for determining their shapes are fully given. Problems illustrate the text throughout. For a lecture course on the kinematics of machines this book would make an accompaniment for which it is well adapted. C. B. R.

6. *British Museum of Natural History: Guide to the Gallery of Birds in the Department of Zoology.* 228 pp., with 24 plates and illustrations. London, 1905.—This guide has been prepared by Mr. W. R. OGILVIE-GRANT, Assistant in the Zoological Department, who has also carried out the arrangement of the collections as now exhibited. An appendix is added on the structure of birds with illustrations of the feathers and skeleton. The numerous full-page plates give reproductions of excellent photographs of actual specimens in the gallery. To those who have not had the opportunity to learn by actual visit the riches of the Museum they will give a good idea of the admirable results attained in the representation of birds in their natural surroundings.

7. *Catalogue of the Lepidoptera Phalænæ in the British Museum*, Vol. V. *Catalogue of the Noctuidæ;* by SIR GEORGE F. HAMPSON. Pp. xvi, 634, with plates lxxviii–xcv. London, 1905.—The publication of the fourth volume of this important work was noticed in the number for February, 1904. The present volume embraces the classification of the Hadeninæ, the second of the fifteen subfamilies of the Noctuidæ; 946 species belonging to 78 genera are described. This subfamily is characterized by its trifid neuration of the hind wing, combined with the hairy clothing of the eyes.

8. *Geographen-Kalender; in Verbindung mit vielen Fachgenossen herausgegeben* von Dr. HERMANN HAACK. Dritter Jahrgang, 1905–1906. 468 pp. Gotha, 1905 (Justus Perthes).—The third issue of this useful calendar contains the good features of its predecessors with some additions and emendations. The address list of geographers and those in allied departments has been much enlarged and made more accurate. The literature of the year 1904 is fully treated, as also the necrology; further, a brief summary is given of interesting events illustrated by a series of sixteen maps. A portrait of Jacques-Elisée Reclus forms the frontispiece.

9. *Publications of the Carnegie Institution.*—The following papers have been recently issued:

No. 23. Heredity of Coat Characters in Guinea-Pigs and Rabbits; by W. E. CASTLE. 78 pp., 6 plates (Papers of Station for Experimental Evolution at Cold Spring Harbor, N. Y., No. 1).

No. 24. Mutants and Hybrids of the Oenotheras; by D. T. MacDougal, assisted by A. M. Vail, G. H. Shull and J. F. Small (Cold Spring Harbor Papers, No. 2). 57 pp.

No. 28. A revision of the Atomic Weights of Sodium and Chlorine; by Theodore W. Richards and Roger C. Wells. 70 pp.—See notice on p. 451.

No. 29. The Color Sensitivity of the Peripheral Retina; by John Wallace Baird. 80 pp.

No. 30. Stages in the development of *Sium cicutæfolium;* by George Harrison Shull. 28 pp. (Cold Spring Harbor Papers, No. 3).

A study of the Conditions for Solar Research at Mt. Wilson, California; by George E. Hale (Contributions from the Solar Observatory of the Carnegie Institution, Mt. Wilson, California, No. 1). 27 pp.—A careful investigation of the climatic conditions upon Mt. Wilson, near Pasadena, California, shows that it offers very great advantages for astronomical work, particularly in the study of the sun and solar radiation. Professor Hale remarks that he knows "no other site that compares at all favorably with it." It is much to be hoped that the plans for the building and equipment of a large solar observatory at this point may be carried rapidly to completion.

10. *Cold Spring Harbor Monographs.* III, The Salt-Marsh Amphipod: Orchestia palustris; by Mabel E. Smallwood. 21 pp. with two plates and a map. Brooklyn, March, 1905. Published by the Brooklyn Institute of Arts and Sciences.

11. *Science Bulletins of the Brooklyn Institute of Arts and Sciences.* Published by the Macmillan Company—The following numbers of volume I have appeared under date of March 31:

No. 5. Mammals from Beaver County, Utah, collected by the Museum Expedition of 1904; by J. A. Allen. Pp. 117–122.

No. 6. Additions to the Coleoptera of the United States with notes on some known species; by Chas. Schaeffer. Pp. 123–140.

12. *Project for the Panama Canal;* by Lindon W. Bates. 38 pp., with several maps and plans.—The author discusses briefly some of the projects that have been proposed for the canal and then presents in full the one which in his judgment is likely to lead to the best results. General plans and profiles are given of the water way, the regulation works, and the terminal harbors.

## Obituary.

Henry R. Medlicott, F.R.S., the eminent English geologist, died on April 6 at the age of seventy-six years. His work was chiefly in connection with the Geological Survey of India, which he joined in 1853 and of which he was the Director from 1876 to 1887.

Professor Pietro Tacchini, the celebrated Italian astronomer, died at Spilamberto, Modena, on the 24th of March, at the age of sixty-seven years.

Professor Otto Struve, Director of the Pulkowa Observatory from 1862–1890, died on April 14, at the age of eighty-five years.

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